The effects of climate change on financial stability, with particular reference to Sweden

A report for Finansinspektionen

(The Swedish Financial Supervisory Authority)

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- Human-induced climate change and its mitigation are fraught with uncertainty. Both entail costs, risks and opportunities for financial sector institutions and their customers. They will both impose extensive structural changes on economies around the world, including Sweden's, affecting the income and balance sheets of savers, insurance companies, banks and other financial intermediaries.
- Climate risk at the aggregate level is significant. Overall, economic studies have associated a 2-3°C increase in the global mean temperature, relative to 1850, with expected impacts equivalent to a loss of GDP in the region of 0-3%. This is relative to a counterfactual projection without climate change and is an effect on the level of GDP, not the growth rate. New research exploiting the statistical relationship between short-run climate fluctuations and GDP suggests that there are strong and non-linear economic responses to changes in short-run average temperatures, so the downside risks to the estimates of aggregate losses are considerable.
- There are virtually no data on impacts of more than 3°C warming, with experts' views diverging widely. But the downside risks of unmitigated climate change are large if more pessimistic views are correct.
- Sweden´s economy is probably less vulnerable to climate change than most European economies, even though temperatures may rise more than the global average given the country's latitude. A full assessment needs to take into account Sweden's links with the rest of the world (e.g. through migration flows and world food prices), the ultimate increase in global temperatures and the speed of climate change.
- Taking action to reduce climate risk creates risks of its own – 'carbon risk' (some use the term ´transition risk´). These two classes of risks are negatively correlated, but both may be underestimated at present. As with any large-scale structural transformation, there are likely to be winners and losers amongst owners of capital assets, owners of reserves of raw materials, and workers, reflecting revised expectations about the future pattern of income-earning opportunities. Financial institutions need to assess their exposure to the losers in order to gauge risk.
- There are two main categories of risk arising from the transition to net zero greenhouse gas emissions or beyond: (i) risks deriving from incomplete and evolving knowledge about the technological and behavioural constraints on the transition, given a known and credible policy framework, and (ii) risks deriving from the interaction of economic agents' beliefs about the climate policies they will face with the behaviour of policy-makers. The term 'carbon risk' is often used for both these categories.
- The costs of the transition need not be large if it is carried out cost-effectively. According to the median study, stabilisation of greenhouse gas concentrations to keep global warming below 2°C would reduce global annualised consumption growth by only 0.06 percentage points, with consumption in 2100 being only 4.8% below the hypothetical 'business as usual with no climate change' level. The costs are likely to be higher for certain industries, especially in the energy sector.
- There is considerable uncertainty about mitigation costs but not as much as about the impacts of climate change itself (especially for global warming beyond 2°C).
- Swedish firms have already adapted to a regime of ever more stringent climate-change mitigation policies and have therefore decoupled emissions and economic activity more than producers in most OECD countries, thanks in part to past policies. This however means that subsequent domestic mitigation measures are likely to be costlier at the margin, as indicated by high effective carbon prices in parts of the Swedish economy.
- Climate risk and carbon risk can each affect the assets and liabilities of financial institutions. Both are subject to evolving uncertainties about the state of the world and about the responses of policy-makers

over time. There are several reasons why it may not be wise for regulators to leave risk management entirely to financial market participants:

  - It is important that regulated firms do not under-report climate risk and carbon risk (by mistake or deliberately to conceal their risk appetite);
  - Market prices for assets may not be set in perfectly competitive markets with full arbitrage opportunities, and therefore may not reflect all information available to market participants. If financial intermediaries attempt to hedge against long-term risks, they may suffer short-run losses and capital outflows;
  - Regulators may be better placed to collect and disseminate information about non-market global risks;
  - Regulators may wish to take special measures to regulate lending to high-carbon firms just as several have done with respect to lending to the property sector already.

- High-carbon sectors of the economy share some of the key characteristics of industry sectors that have triggered financial crises in the past: they are capital-intensive; they use relatively long-lived assets; they are a significant portion of the economy; and they are largely debt-financed.
- An experimental estimate of the mean value-at-risk (VaR) from climate change for the world's financial assets is 2.9% in a so-called business-as-usual scenario for global greenhouse gas emissions, which corresponds with roughly 2.5°C warming by 2100. This is a mean estimate of the losses on financial assets imposed by climate change in this scenario compared with a counterfactual world in which climate change does not take place. However, if warming instead reaches 5°C or even 6°C by 2100, the VaR is much higher. These latter scenarios can be interpreted as tail probabilities. If instead carbon emissions are controlled such that the increase in the global average temperature stays below 2°C (in expectations), the mean VaR is only 1.5%.
- Mean VaR values are considerably lower than the standard deviation of annual stock market movements (which has been of the order of 20% for the Dow Jones Industrial Index). However, it can be argued that stock markets suffer from excess volatility, so increases in climate risk could trigger larger stock price movements than the VaR numbers suggest. The risk is likely to be difficult to hedge given the global incidence of adverse climate change impacts. VaR will also be larger if sudden changes in valuation trigger macroeconomic downturns. And the estimates do not take into account the full extent of short-run volatility that stems from extreme weather.
- The VaR with respect to assets owned by Swedish banks and investors is probably lower than the global estimate, because, first, climate change is expected to impact economic growth less in Sweden than elsewhere, and, second, because Swedish investors naturally hold a disproportionate share of Swedish assets.
- The introduction of strong climate-change mitigation policies could create 'stranded assets': assets that have suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities. These could include a large fraction of the assets of listed fossil-fuel firms as their reserves become 'unburnable carbon.'
- Swedish pension funds tend to have a lower-than-average exposure to high-carbon assets. The bank Nordea may have a relatively high exposure to high-carbon loans, equities and bonds. But more information is needed about exposures across financial institutions.
- Global insured losses due to extreme weather events are on a long-term and statistically significant increasing trend. Up until now, this appears largely attributable to an increase in the value of insured assets. But the role of climate change, which is likely to increase the frequency of extreme weather events, is becoming larger. Sweden's direct exposure to natural hazards is low by global standards but Swedish insurers also face risks elsewhere in the world.

- The Bank of England Prudential Regulation Authority recently concluded that general insurers in the UK are "reasonably well equipped to manage the current level of direct physical risks." A similar conclusion seems appropriate for Sweden.

- Overall, this report does not suggest that climate change and its mitigation pose major new risks for Swedish financial firms or Swedish financial stability. But these are relatively recently studied categories of risk. Understanding of climate science and economics is evolving fast and the policy environment is changing rapidly too. In this situation, there is merit in regulators, including FI, considering whether:
  - supervised institutions should carry out climate- and carbon-risk stress tests;
  - regulators should carry out macroprudential stress tests with a 'carbon risk' dimension, perhaps by recalibrating the fossil fuel price shocks often included in such stress tests;
  - carbon disclosure should be improved and common disclosure standards established;
  - the fiduciary responsibilities of financial firms with respect to disclosure standards and climate-related societal objectives should be clarified;
  - new climate finance instruments and carbon markets require regulatory initiatives.
- It would also be useful to monitor the emerging debate about adapting bank capital standards to favour long-time-horizon low-carbon projects. It is, however, not clear that this would be the best way of encouraging investment in such projects given the danger that management of their financial risks might be impaired.

2. Introduction

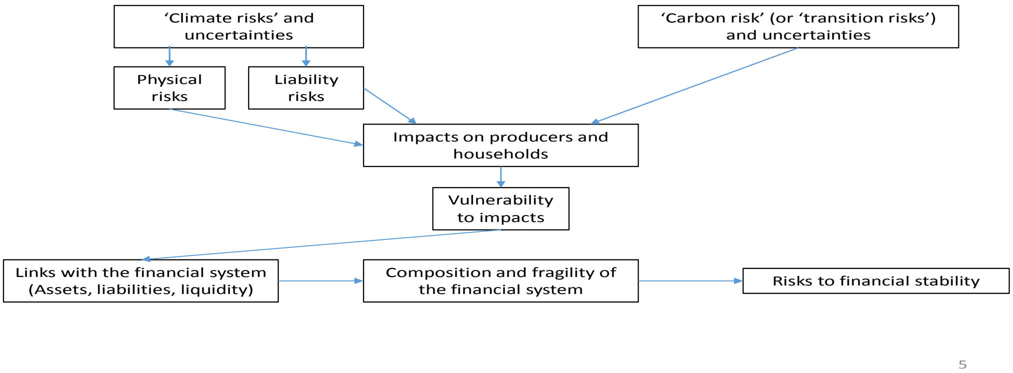
This report constitutes a part of the response to a request from the Swedish government to "Analyse and in a written report outline how environmental and climate change may affect financial stability in the long run, and which measures may be needed to dampen the negative effects on the financial system" (Appropriation direction FI2015/3195).

The 21st Conference of the Parties to the UN Framework Convention on Climate Change in Paris in December 2015 has once again raised public awareness about the pervasive ramifications of climate change and its mitigation. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change, published in 2014, collated extensive evidence about the impacts of climate change and its mitigation on economies around the world. Although these impacts will differ according to geographic factors, endowments of resources, income levels and economic structures, no countries, including Sweden, will be left untouched.

The financial sectors of economies will be amongst those affected, giving rise to risks to financial firms, not least because the prospects for climate change and its mitigation are fraught with uncertainty. Both entail costs, risks and opportunities for financial sector institutions and their customers. For example, climate change is increasing the risk of large losses to insurers from extreme weather events. It also raises the possibility of litigation about who is legally responsible for climate-related natural disasters. These are examples of 'climate risks'. Policies to reduce greenhouse gas emissions may undermine the business plans and reduce the value of fossil-fuel owning firms and energy-intensive companies. They may also lead to sharp changes in the direction of financial investment flows. These are examples of 'carbon risk.' Both categories of risk affect asset managers and financial intermediaries, given the possible impacts on asset valuations, creditworthiness and cash flows. In April 2015, the G20 group of countries asked the Financial Stability Board (FSB) to convene a review of how the financial sector "can take account of climate-related issues."[i] A number of central banks – including the European Central Bank, the Bank of England and the central banks of China, Bangladesh and Brazil – are already taking explicitly climate-related actions (UNEP 2015). As Governor Mark Carney of the Bank of England has said, "Forward-looking regulators consider not just the here and now, but emerging vulnerabilities and their impact on business models" (Carney 2015).

This report reviews the nature of 'climate risk' and 'carbon risk', noting their significance while also drawing attention to the uncertainties in climate science, economics and policy. It then goes on to consider how these categories of risk are likely to interact with financial sectors and why regulators should consider these interactions on micro- and macroprudential grounds. Where possible, the risks in the Swedish context are analysed. The structure reflects the schematic representation of the connections between climate-related risks and the financial sector shown in Figure 1. The report concludes with a brief discussion of some policy issues for regulators that emerge from this review.

Figure 1. Climate-related risks and their impact on financial sectors



2. Climate risk

2.1. A framework for understanding climate risk and the state of knowledge

This section offers a conceptual framework for understanding climate risk in terms of the linkages between physical changes in the climate system and the economy, and uses this framework both to characterise the current state of knowledge on climate risk (to the economy) and the stylised facts that have emerged from research on the topic.

It is possible to distinguish three types of physical change to the climate system, which can have economic consequences:

1. Slow-onset or chronic hazards: i.e. the gradual increase in average temperatures and sea levels, and gradual changes in average precipitation.
2. Extreme weather: i.e. compared with (1), these are sudden-onset, acute hazards. Climate is usually defined as the distribution of weather, and in recent years there has been increasing focus on the capacity of climate change to make extreme weather events, e.g. heat waves, droughts and storms, more likely (IPCC 2012).
3. Tipping elements in the climate system: the term 'tipping elements' has been coined (Lenton et al., 2008) to capture a set of climate processes, which are globally significant, and for which a relatively small increase in greenhouse gases could trigger a major shift in their mode of operation. Relevant examples include over-turning of the Atlantic thermohaline circulation, which, among other things, keeps North-western Europe warmer than other regions at the same latitude, and rapid decay of the Greenland ice sheet, which would eventually contribute several meters to global sea levels.

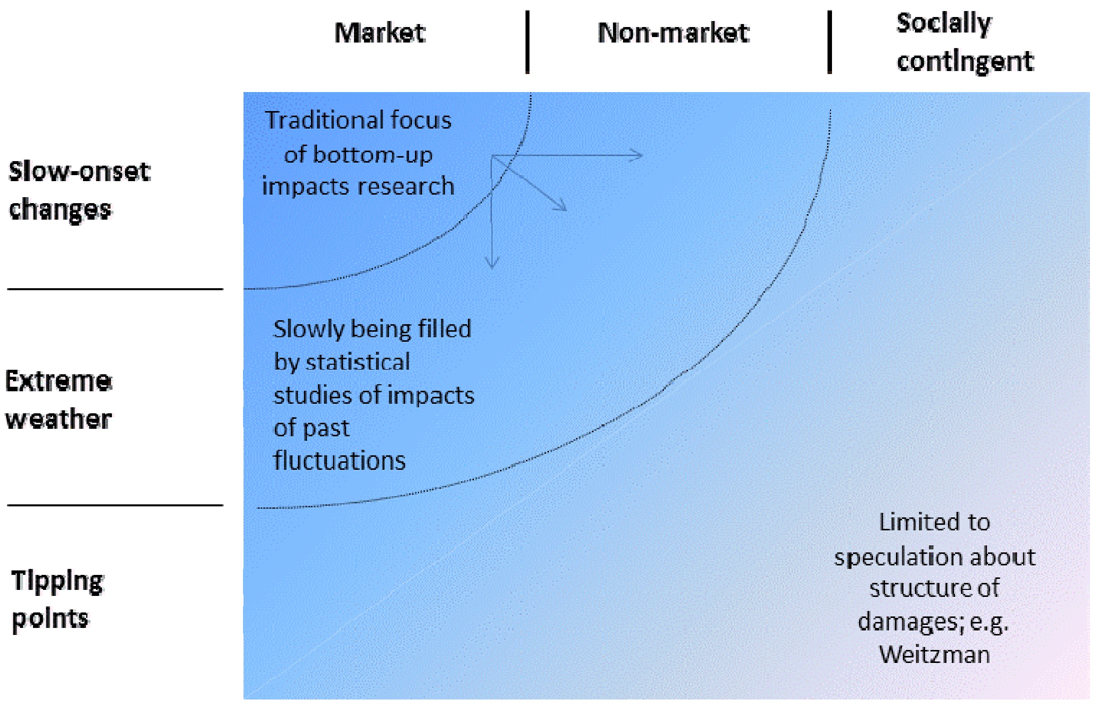
Similarly it can be useful to distinguish various ways in which these physical changes can have economic impacts. The following typology was employed by the *Stern Review* (2007):

- Market impacts: these are impacts on economic activities where market prices exist, e.g. agriculture, forestry (including timber and paper) and energy. They are likely to affect the value of related financial assets, such as equity shares in agribusinesses. Sometimes negative impacts of climate change, such as expansion of the construction sector after a storm in order to repair and reconstruct, are associated with an increase in economic output. Economists classify such phenomena as so-called 'defensive' or 'averting' expenditures and count them as costs of climate change.

- Non-market impacts: these are impacts on other elements of human well-being that are not priced in markets, e.g. aspects of human health, and some ecosystem services or in other words changes in the natural environment. From an economic point of view it is important to measure such impacts, because they are demonstrably related to human welfare. However, pure non-market impacts are generally of less relevance to financial-asset valuation. The underlying problem that prevents market prices from emerging – a lack of property rights – also prevents the creation of financial assets out of such goods/services.
- Socially-contingent impacts: these are indirect impacts mediated by macro-scale human behavioural responses, e.g. conflict, migration and flight of capital investment.

With this conceptual framework in mind, it is possible to consider how the body of research that has been amassed on the economic impacts of climate change matches up (Figure 2). This matrix updates and adapts Figure 6.3 in the *Stern Review* (Stern 2007).

Figure 2. Coverage of research on the economic impacts of climate change



Source: adapted from updated from Stern (2007), ch. 6

Traditionally, research on economic impacts has built up from the bottom with specific analysis of climate-sensitive economic activities like agriculture and forestry. The focus has usually been on modelling how slow-onset changes, particularly warming, affect production.

More recently, economists have been able to study economic impacts by matching data on variations in temperature over relatively short time-scales, e.g. fluctuations in annual averages, with economic data like GDP. Hence this research tends to focus on the impacts of extreme weather. It is complemented by other studies of extremes, such as event studies and simulation models. As far as tipping elements/points in the climate system and socially contingent responses are concerned, there is little empirical evidence on which to inform conclusions at present. In its absence, the educated guesses have been influential (Weitzman 2012; Dietz & Stern 2015).

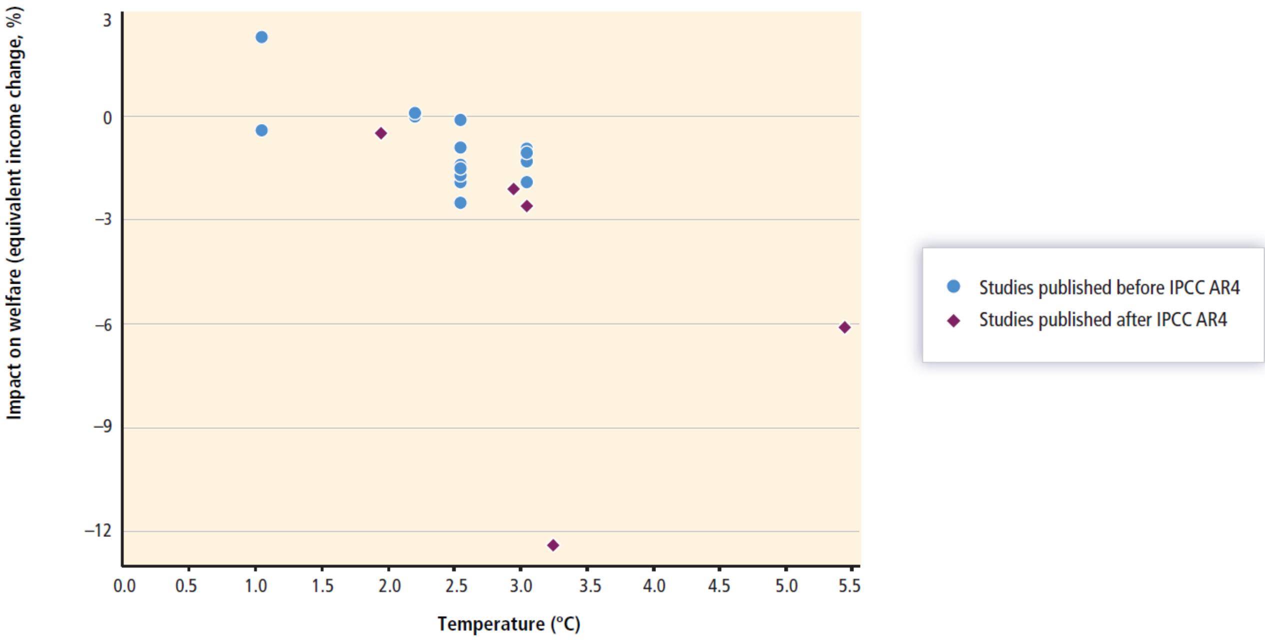
Overall, coverage of the market impacts of slow-onset climatic changes is relatively comprehensive, while understanding of the market impacts of extreme weather is advancing fast. However, 'tail' scenarios involving tipping points and/or large-scale human responses like conflict and migration are poorly understood. It is sometimes observed of this situation that we are counting what we can measure rather than necessarily measuring what counts. Moreover, even where coverage is good, there remain many research challenges. Overall, it is difficult to over-state the degree of uncertainty attending to the economic impacts of future climate change.

2.2. Stylised facts on the economic impacts of climate change

Relatively more research effort has been focused on the global aggregate picture, since it directly informs questions about economically efficient global emissions targets. We will also start here, since it helps to fix ideas about the potential magnitude of the economic impacts in question, and the range of uncertainty around them.

Figure 3, reproduced from Arent et al. (2014), collects together all the estimates of the global economic impacts of climate change considered independent. Overall, economic studies have associated a 2-3°C increase in the global mean temperature, relative to 1850, with impacts equivalent to a loss of GDP in the region of 0-3%. This is relative to a counterfactual projection without climate change, i.e. it is an effect on the level of GDP, not the growth rate. To put this in a temporal context, we could see 2°C warming, over 1850, by 2030 at the earliest, although on the balance of scenarios it is a point we might be more likely to reach in the second half of this century (IPCC 2013). With significant efforts to cut global greenhouse gas emissions, we may avoid it altogether.

Figure 3. Estimates of the global economic impact of climate change



Source: Arent et al. (2014)

There are virtually no data on impacts of more than 3°C warming, with experts' views diverging widely. Some economists believe impacts will remain relatively mild (equivalent to below 10% of GDP, say), while others such as the Harvard economist Martin Weitzman and Lord Nicholas Stern, conjecture that they will assume catastrophic proportions. Overall, it seems reasonable to conclude in the face of this disagreement and the lack of evidence that scenarios of very severe impacts cannot be ruled out. They may at least be ascribed to the tail of the distribution.

New research exploiting the statistical relationship between short-run climate fluctuations and GDP – a method described above – is challenging these 'traditional' findings. A significant new study (Burke et al. 2015) suggests that there are strong and non-linear economic responses to changes in short-run average temperatures. If these would be extrapolated to try to understand the potential impacts of long-run changes, as in Figure 3, then the estimates appear to be of an altogether different order of magnitude. According to Burke et al., 2°C warming might result in a c. 30% loss in GDP. However, it is unclear whether extrapolating in this way is appropriate.

A smaller number of studies look at the impacts of climate change in general equilibrium, i.e. looking explicitly at links between sectors and allowing prices to change as climate change shocks the system. They find that (IPCC 2014b):

- Impacts are indeed transmitted across locations and across multiple sectors of the economy;
- Price changes can benefit producers while hurting consumers and vice versa;
- The distribution of the direct impacts can be very different than the distribution of the indirect effects;
- A loss of productivity or productive assets in one sector leads to further losses in the rest of the economy;
- 'Market-driven adaptation' tends to produce lower final/overall impacts.

2.3. Economic vulnerability of Sweden to climate change

Economic modelling tends not to disaggregate to the level of individual countries, rather dealing with larger regions. Northern Europe is sometimes singled out. What such studies tend to show is that Northern Europe is relatively less vulnerable to climate change than other parts of the world.

Indeed, a stylised fact from research comparing impacts worldwide is that the most vulnerable countries are low-income, low-latitude countries, due to a combination of adverse physical changes (they are already hotter than is optimal for economic activity and many suffer extreme variability of rainfall, etc.), high sensitivity to climate (e.g. a large agricultural sector as a share of the national economy), and low capacity to adapt, the latter two factors being of course linked with low development levels.

By contrast, high-income, high-latitude countries may see some positive physical changes (being in general cooler than is optimal for economic activity) and tend to be less sensitive to climate. Looking at the breakdown of Swedish economic activity by sector (Table 1), climate-sensitive sectors such as agriculture, forestry, energy, tourism and water, and related manufacturing industries, i.e. food processing and manufacturing of wood and paper products, comprise a small share of the national economy.

Table 1. Share of Swedish GVA from climate-sensitive sectors

Sector	*Percentage of national gross value added*
A01-A03 agriculture, forestry and fishing	1.4
C10-C12 manufacture of food products, beverages and tobacco products	1.2
C16-17 manufacture of wood and paper products	1.5
D35 electricity, gas, steam and air conditioning supply	2.6
E36-E37 water supply and sewerage	0.3
I55-I56 hotels and restaurants (proxy for tourism)	1.7

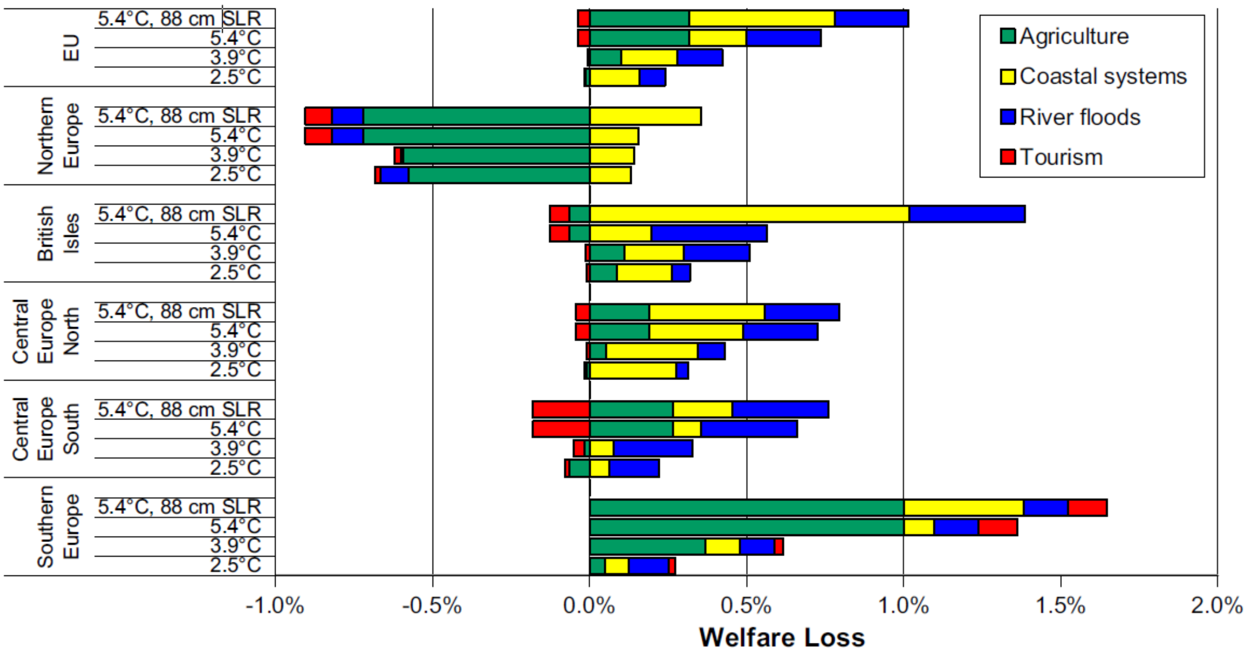
Source: 2013 data from Statistics Sweden

Even within Europe, the balance of evidence suggests that Southern Europe will see relatively more adverse impacts than other parts of the continent. Indeed, several studies, including one of the most important and rigorous to be carried out at this level of disaggregation (Ciscar et al. 2011), suggest that climate change might be net beneficial to Northern Europe, due in particular to a substantial increase in agricultural production as a result of higher temperatures (Figure 2.3). Other studies corroborate this finding of net economic benefits (Bosello et al. 2012; Burke et al. 2015).

Similarly IPCC finds a majority of studies into the agricultural and forestry sectors in Northern Europe report a positive impact on production, while it concludes from an assessment of the literature that the impacts on energy-sector production (specifically wind and hydro) should also be positive on balance (Kovats, R.S., R. Valentini, L.M. Bouwer, E. Georgopoulou, D. Jacob, E. Martin, M. Rounsevell 2014).

There are several important caveats to this finding. For one, it is evident that the particular study featured here only analyses a small subset of all the possible impacts of climate change, although the same criticism applies less to other studies that identify the same direction of effect, in particular Burke et al.(2015). It does not feature extreme weather events, for instance, and these are a potentially serious threat to any gains in agricultural production, which might result from gradual increases in temperature. IPCC anticipates an increase in the frequency of heavy precipitation in Sweden due to climate change, with 'high confidence' (Kovats, R.S., R. Valentini, L.M. Bouwer, E. Georgopoulou, D. Jacob, E. Martin, M. Rounsevell 2014). Farmers themselves appear more pessimistic than the models (Olesen et al. 2011).

Figure 4. Economic impacts of climate change on European regions



Source: Ciscar et al. (2011)

However, it is difficult to say with confidence whether studies such as these under-estimate the negative impacts climate change could have on Sweden, or over-estimate them, because there are many limitations. Ciscar et al. (2011), for instance, make pessimistic assumptions about the adaptability of European economies to climate change, because in their model they impose future climatic conditions on today's economic structure. And some of the sectors their study omits, such as forestry, may also see increases in production, as mentioned just above.

It might be reasonable to conclude that, despite the fact that it will experience some of the largest physical changes, in particular the largest temperature changes, Sweden is not among the European countries *most* directly vulnerable to climate change, without speculating on whether the impacts are net costly or net beneficial overall.

There is of course the additional question of to what extent Sweden is indirectly vulnerable to climate change. Section 2.2 emphasised the importance of indirect links between national economies. In fact, the results shown in Figure 4 already incorporate indirect links between European economies. Other research that explicitly separates direct and indirect effects for Northern Europe shows that the indirect effects dampen any negative direct effects (Bosello et al. 2012). The mechanism behind these results is 'market-driven adaptation', as identified above. This study is also notable for incorporating indirect links between the Swedish economy and the rest of the world as a whole, not just the rest of Europe.

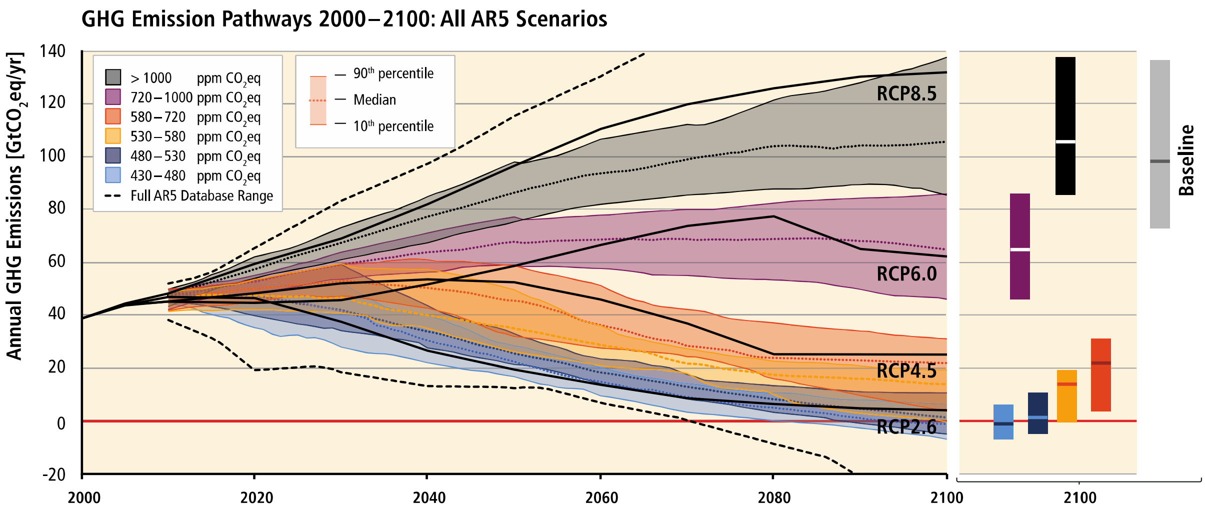
3. Carbon risk

3.1. A framework for understanding carbon risk and the state of knowledge

Taking action to reduce climate risk creates risks of its own. Climate-change mitigation requires changing production and consumption decisions by firms and households in such a way as to reduce net emissions of greenhouse gases (GHGs) from around 50 $GtCO_2$ equivalent (50 $GtCO_2e$) per year ultimately to around or below zero, to prevent the atmospheric concentration of GHGs continuing to increase. This means that policy-makers must try to induce significant, pervasive and permanent changes in the structure of the global economy, to achieve substitution of low- and zero-GHG goods and services for (currently) high-carbon ones in both production and consumption and to stimulate technical progress to reduce the costs of producing low- and zero-GHG goods and services. Such structural changes produce winners and losers

Figure 5 illustrates the scale of the change needed in annual emissions. It shows various trajectories for annual GHG emissions consistent with stabilising GHG concentrations at different levels. Those labelled RCP2.6 are consistent with keeping the probability of the global temperature rise exceeding 2°C to less than one in three (concentrations stabilise in the range of 430 to 480 parts per million CO_2e). On these trajectories, global emissions must peak and start to drop within the next ten years and must fall far below the paths assumed in most baseline scenarios (which are similar to those labelled RCP8.5 in Figure 5).

Figure 5. Projected paths for greenhouse gas emissions for different scenarios



Source: Figure SPM.4 (upper panel) from IPCC, 2014a: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Executive Summary of chapter 11. [Edenhofer, O., R. Pichs-Madruga, Y.Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schloemer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

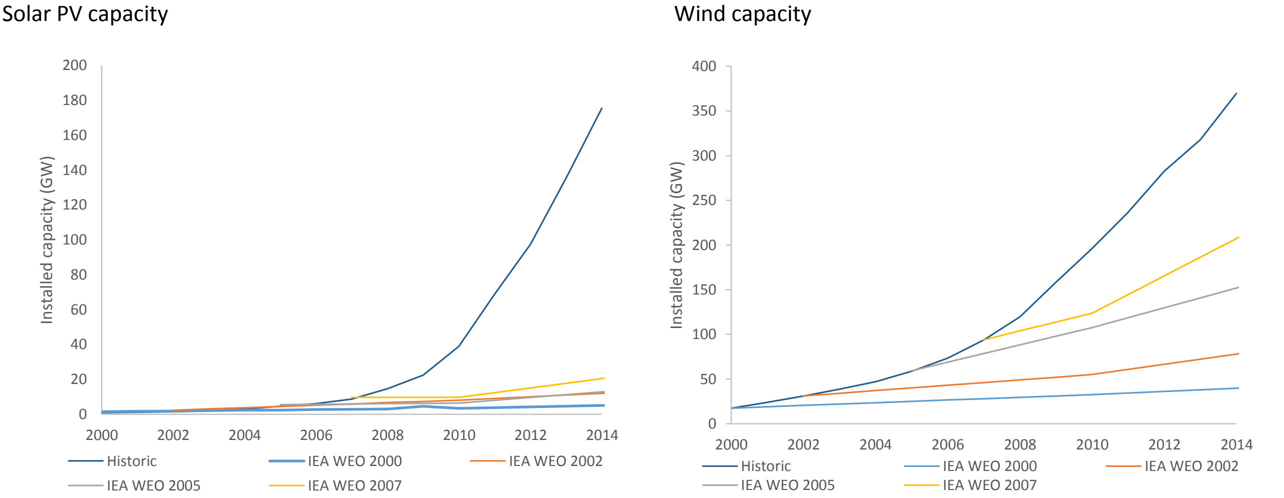
Note: RCP denotes 'representative concentration pathway.' RCP2.6 denotes the range of pathways that reach radiative forcing of 2.6 Watts per square metre in 2100 relative to 1750, where radiative forcing is the difference between the sun's energy absorbed by the Earth and the energy radiated back to space. Dotted lines in colour denote the median pathway for each set of pathways.

As with any large-scale structural transformation, there are likely to be winners and losers amongst owners of capital assets, owners of reserves of raw materials, and workers, reflecting revised expectations of the future pattern of income-earning opportunities. In particular, the introduction of effective climate change mitigation is likely to reduce the value of stocks of hydrocarbons such as coal, natural gas and oil, given that these are a major source of CO_2 emissions (this is discussed further below in the context of global carbon budgets and the concept of 'unburnable carbon'). Owners of these stocks are therefore subject to 'carbon risk.' This term is often used as short-hand for all the risks arising from the transition to a zero-net-emissions global economy, although the term used by the Bank of England's Prudential Regulation Authority, 'transition risks,' more accurately captures the fact that there are many risks and uncertainties about the transition (Prudential Regulation Authority 2015).

There are two main categories of risk arising from the transition to net zero emissions or beyond: (i) risks deriving from incomplete and evolving knowledge about the technological and behavioural constraints on the transition, given a known and credible policy framework, and (ii) risks deriving from the interaction of economic agents' beliefs about the policies they will face with the behaviour of policy-makers.

In the first category are factors such as the degree of substitutability of low-carbon inputs for high-carbon ones in the short and the long run. The costs of low-carbon energy sources, such as electricity from renewable energy sources and nuclear power, relative to those of fossil fuels are one important source of uncertainty. The future pace of carbon-reducing technical progress and the rapidity with which low-carbon technologies are adopted are also uncertain, in part because the speed with which costs will fall as firms gain greater experience with a technology is difficult to predict. Figure 6 illustrates, for example, how the International Energy Agency has consistently underestimated the speed of diffusion of wind and solar power. The speed at which important new technological ideas emerge varies considerably, which is not surprising given how a small number of innovations account for most of the returns to research and development, judging by the highly skewed returns to patents (Schankerman & Pakes 1986; Gambardella et al. 2008). Another uncertainty is the extent to which the energy intensity of production of various goods and services can be reduced, for example, by using 'smarter' (and more costly) plant and equipment. Also, the willingness of people, given various incentives, to change their patterns of consumption to reduce their carbon footprints is not known with certainty. If policy-makers use taxes and subsidies to provide incentives for transitioning to a low-emissions world, these price signals are likely to have wide-ranging impacts on the allocation of natural resources, capital, labour and spending across economies. These impacts are difficult to anticipate fully if the behaviour of economies is not fully understood.

Figure 6. IEA solar PV and wind capacity forecasts against actual



Source: Carbon Tracker, 2015 (Figures i.1 and i.2, p.7)

Another important risk arises from uncertainty about the long-run trajectory of global output. The higher it is, the higher are greenhouse gas emissions likely to be, other things equal. Hence the higher is the future rate of world growth, the bigger will be the challenge and expense of reducing net emissions to or below zero by any given date. However, there is great uncertainty about the future trajectory of global output. For example, on the one hand, many adverse shocks to global growth, such as the financial crisis of 2007-08, have long-lasting impacts on the level of output, shifting output trajectories downwards rather than temporarily reducing output below its previous trend. Such persistent adverse shocks make it easier and cheaper to achieve the necessary reduction of emissions. On the other hand, major technological advances such as the IT revolution raise the expected trajectory of output, making decarbonisation by any given date harder.

As a result of such factors, the costs of climate change mitigation are uncertain. So is the extent of potential co-benefits from climate-change mitigation, such as reductions in particulate pollution and increases in labour productivity (co-benefits are discussed extensively in Global Commission on the Economy and

Climate, 2014). The existence of such co-benefits cuts the net cost of climate change mitigation and warrants tougher climate-change policies.

The second category of risks arises because climate change mitigation requires collective action on a global scale over a long period. Policy-makers have to adjust policy instruments such as the issuance of emissions quotas as they learn about how the economy reacts to climate-related policies and as new information is received about climate change risks and the parameters determining the evolution of economies (i.e. as risks in the first category change). However, firms and households may find it difficult to assess the justification for policy changes and may not be able to distinguish between policy changes due to new information and policy changes due to policy-makers succumbing to moral hazard and time inconsistency. For example, firms may fear that policy-makers will be tempted to withdraw promised renewable energy subsidies or to cut carbon taxes to reduce costs to consumers, but only once firms have already invested in low-carbon plant and equipment. Different parts of government, such as environment and energy ministries, may weigh competing objectives (such as emission reduction targets and low unit costs of energy) differently. Private firms have to make a judgement about which objectives will win out. Policy-makers in one country may take advantage of low-emissions policies in other countries to try to attract high-emissions producers, thereby establishing 'pollution havens' and free-riding on other countries' commitment to climate-change mitigation, provoking uncertain policy reactions in those other countries. In such circumstances, events changing views about policy-makers' likely behaviour, such as elections, legislation and international agreements, can bring about abrupt changes in other agents' behaviour and have large-scale implications for asset values and the pace and direction of structural change.

3.2. Stylised facts on the economic impacts of climate-change mitigation

The costs of climate-change mitigation are usually estimated by using large-scale global economic models to compare scenarios with different GHG emissions paths, with the structure of the global economy determined by some form of optimisation subject to the emissions path constraint or (less commonly) by econometrically estimated reaction functions. Sharper reductions in emissions over time entail more rapid transformation of economies (particularly their energy sectors) in the model scenarios and lower paths for GDP and aggregate consumption. The costs of climate-change impacts themselves and of adaptation to climate change are not usually included in the analysis, so that the reference case is often a scenario with unchanged policies ('business as usual' or BAU) in a counterfactual world of no climate change. Working Group III's section of the Intergovernmental Panel on Climate Change's Fifth Assessment Report (2014) summarises the range of cost estimates (Figure 7 below). Table 2 shows that the median study among those projecting stabilisation at targets between 430 ppm and 480 ppm estimates that climate-change mitigation would reduce global annualised consumption growth by only 0.06 percentage points, with consumption in 2100 being only 4.8% below the 'BAU with no climate change' level. If certain key technologies are unavailable for any reason, that would increase the costs of mitigation; on this metric, carbon capture and storage is the most important technological option. Delaying an increase in mitigation efforts to 2030 (while maintaining the same atmospheric concentration target) would also increase total costs.

There is considerable uncertainty about mitigation costs, as illustrated by the range of model projections. For example, the impact on consumption in 2100 ranges from 2.9% at the 10^{th} percentile to 11.4% at the 90^{th} percentile of estimates. As the IPCC Fifth Assessment Report notes, "Estimates of the aggregate economic costs of mitigation vary widely and are highly sensitive to model design and assumptions as well as the specification of scenarios, including the characterization of technologies and the timing of mitigation." Models and estimates also vary widely in terms of the time profile of and the regional distribution of projected costs. The incidence of costs across individual economies is often not modelled and, when it is, the pattern depends heavily on the assumptions made about how the macroeconomy works (Bowen 2014). Modelling exercises rarely report uncertainty ranges for individual scenario projections. The studies considered in the IPCC Fifth Assessment Report imply that the riskiness of aiming to keep below a global temperature increase of 2°C is much less than the riskiness of unabated climate change, in terms of both mean expectation of costs and the distribution of possible outcomes. Nevertheless, for individual countries, firms and households, the degree of uncertainty about the costs they will have to bear in the future because of climate-change mitigation is considerable, as illustrated by the wide range of estimates of the price of carbon that will be needed in the future to meet the international community's climate objectives (see IPCC, 2014a, Section 6.3.6).

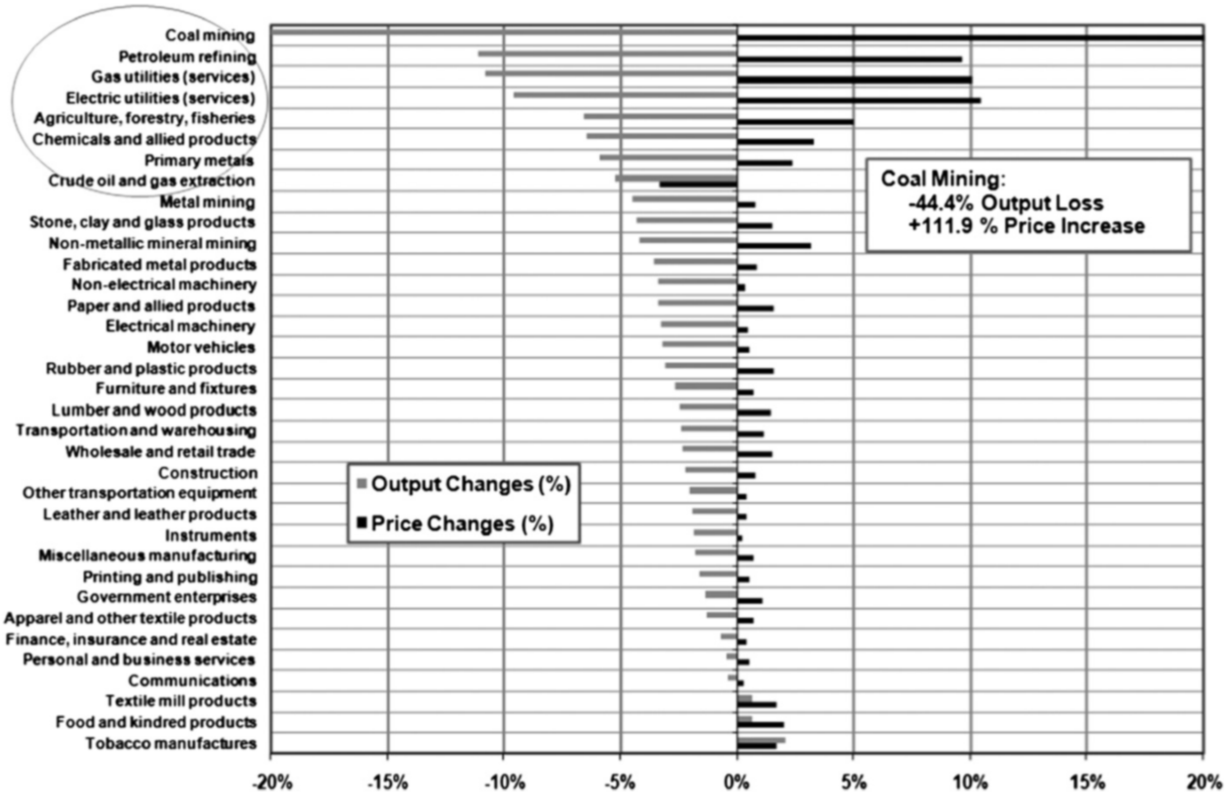
Table 2. Global mitigation costs in cost-effective scenarios and estimated cost increases due to assumed limited availability of specific technologies and delayed additional mitigation

	Consumption losses in cost-effective scenarios[1]				Increase in total discounted mitigation costs in scenarios with limited availability of technologies				Increase in medium- and long-term mitigation costs due to delayed additional mitigation until 2030			
	[% reduction in consumption relative to baseline]			[percentage point reduction in annualized consumption growth rate]	[% increase in total discounted mitigation costs (2015–2100) relative to default technology assumptions]				[% increase in mitigation costs relative to immediate mitigation]			
									≤ 55 $GtCO_2eq$		>55 $GtCO_2eq$	
2100 Concentration [ppm CO_2eq]	2030	2050	2100	2010–2100	No CCS	Nuclear phase out	Limited Solar/Wind	Limited Bioenergy	2030–2050	2050–2100	2030–2050	2050–2100
450 (430–480)	1.7 (1.0–3.7) [N: 14]	3.4 (2.1–6.2)	4.8 (2.9–11.4)	0.06 (0.04–0.14)	138 (29–297) [N: 4]	7 (4–18) [N: 8]	6 (2–29) [N: 8]	64 (44–78) [N: 8]	28 (14–50) [N: 34]	15 (5–59)	44 (2–78) [N: 29]	37 (16–82)
500 (480–530)	1.7 (0.6–2.1) [N: 32]	2.7 (1.5–4.2)	4.7 (2.4–10.6)	0.06 (0.03–0.13)	N/A	N/A	N/A	N/A				
550 (530–580)	0.6 (0.2–1.3) [N: 46]	1.7 (1.2–3.3)	3.8 (1.2–7.3)	0.04 (0.01–0.09)	39 (18–78) [N: 11]	13 (2–23) [N: 10]	8 (5–15) [N: 10]	18 (4–66) [N: 12]	3 (−5–16) [N: 14]	4 (−4–11)	15 (3–32) [N: 10]	16 (5–24)
580–650	0.3 (0–0.9) [N: 16]	1.3 (0.5–2.0)	2.3 (1.2–4.4)	0.03 (0.01–0.05)	N/A	N/A	N/A	N/A				

Source: Table SPM.2, IPCC, 2014a: Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

The structural change induced by climate-change mitigation policies is likely to be greatest in the sectors producing and distributing energy and in the sectors producing greenhouse gases as a by-product of their production processes. This is well illustrated by a study of the potential impact of introducing GHG emissions trading in the USA (Goettle & Fawcett 2009). The study assumes that a limit is placed on cumulative US GHG emissions from 2012 to 2050 such that annual emissions fall to 50% of their level in 1990 by 2050. Receipts from auctioning emissions quotas are distributed to households by means of lump-sum transfers and the policy intervention is assumed to be deficit- and revenue-neutral in nominal terms. The biggest proportional changes in 2030 in output across 35 industries are shown in Figure 7. Impact of cutting US GHG emissions to 50% of their 1990 levels by 2050, starting in 2012, with the most affected industries circled in the top left-hand corner. Coal mining is by far the most heavily hit. These industries are the ones most likely to see corporate valuations written down in response to the imposition of carbon pricing. However, these are relatively small industries. The biggest GDP losses are actually in wholesale and retail trade and electrical machinery. Output actually increases relative to the baseline scenario in textile mill products, food and kindred products, and tobacco manufacture. At this level of granularity, it is not possible to identify the sectors that will benefit from new low-emissions technologies (although the authors of this study do assume some technological innovation is induced by carbon pricing). Among the more GHG-intensive industries at a more disaggregated level are cement manufacture, aluminium smelting, iron and steel, plastics, pulp and paper and fertiliser production.

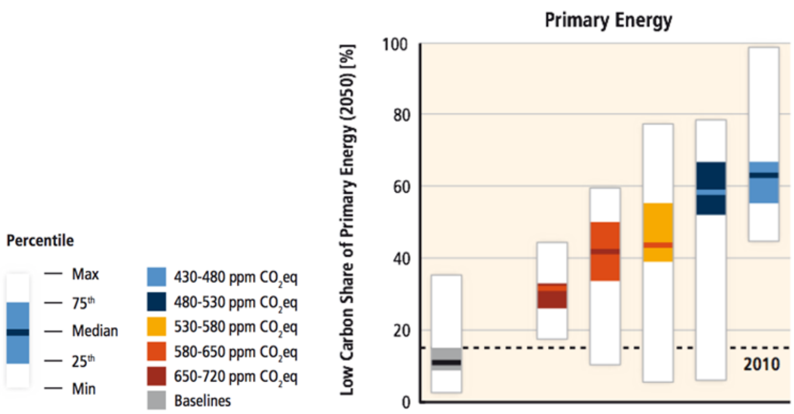
Figure 7. Impact of cutting US GHG emissions to 50% of their 1990 levels by 2050, starting in 2012



Source: Figure 7, Goettle and Fawcett (2009)

Within the energy sector, the mix of energy supply across fossil fuels, nuclear power and renewable energy sources is likely to change as a result of climate-change mitigation. The IPCC's Fifth Assessment Report makes clear that there is considerable uncertainty about the contributions likely from different technologies, especially nuclear, carbon capture and storage (CCS) and biofuels. The contribution that enhanced energy efficiency will make to reducing final demand for energy is also uncertain. But it is clear that low-carbon energy sources are likely to displace fossil fuels to a large extent in stringent mitigation scenarios. For example, the column on the extreme right in Figure 8 shows that, according to the median projection among those reviewed by the IPCC, the share of low-carbon energy in total primary energy supply by 2050 will have to be more than 60%. Keeping global temperature increase below 2°C is likely to entail the complete phasing out of fossil fuels without CCS by 2100. Decarbonisation is likely to take place sooner in power supply than in the transport, buildings and industry sectors.

Figure 8. The share of low-carbon energy sources in total primary energy supply in 2050



Source: Figure 7.14 of IPCC AR5 WGIII

3.3. Sweden and the transition to a low-emissions economy

Sweden is already a relatively low-emissions economy. According to OECD (2014),

> "Sweden has shown a longstanding commitment to mitigating emissions of greenhouse gases (GHGs) both domestically and internationally. Sweden significantly overachieved its Kyoto Protocol target, and projections show it is on track to meeting its 2020 targets of cutting emissions from sectors not covered by the European Union emission trading system (EU-ETS)… Domestic GHG emissions have declined by nearly 16% since 2000, and particularly sharply since the mid-2000s; they have been absolutely decoupled from economic growth… With 51% of renewable energy in gross final energy consumption in 2012, Sweden has already exceeded its renewables policy objectives for 2020. Between 2000 and 2012, renewables supply grew by 18% to reach 35% of total energy supply, the fourth highest share among OECD member countries."

Sweden's CO_2 emissions per capita are well below the world average, let alone the OECD average. Yet thanks to its industrial structure and the high energy consumption of households due to the climate, it does not have a particularly low energy intensity of GDP (Table 3). The unusual aspect of Sweden's energy system is the low emissions intensity of energy, due to high utilisation of renewable energy sources and nuclear power (Table 4). The carbon intensity of the economy is the second lowest amongst OECD member countries.

Table 3. Measures of energy and carbon intensity for Sweden, the OECD and the world, 2013

Variable	*Unit*	*Sweden*	*OECD*	*World*
TPES/GDP	toe/'000 US$	0.11	0.13	0.24
CO_2/TPES	tCO_2/toe	0.76	2.27	2.38
CO_2/GDP	kgCO_2/2005 US$	0.09	0.30	0.57
CO_2/POP	CO_2/capita	3.91	9.55	4.52

Source: IEA, http://www.iea.org/statistics/statisticssearch/ accessed 01/12/2015

Note: TPES denotes total primary energy supply, toe tonnes of oil equivalent, and POP population

Table 4. Composition of primary energy supply for Sweden, the OECD and the world, 2013

Resource	*Sweden*	*OECD*	*World*
Nuclear	34.6	9.7	4.8
Hydro	10.5	2.3	2.4
Biofuels/waste	23.0	5.5	10.2
Geothermal/solar/wind	2.2	1.7	1.2
Coal	4.4	19.4	28.9
Oil	23.4	35.6	31.1
Natural gas	1.9	25.9	21.4

Source: IEA, http://www.iea.org/statistics/statisticssearch/ accessed 01/12/2015

As carbon pricing has been a feature of Swedish environmental policy since 1991, industry has had some time to adjust its expectations about the stringency of climate-change policies. The full rate of carbon tax is amongst the highest in the world, although it is not applied throughout the whole economy. Energy-intensive industries such as pulp and paper have already had to make adjustments to their production technologies, product mixes and R&D strategies in response to carbon pricing and to past increases in fossil fuel prices (Lindmark et al. 2011).

Sweden has established the ambitious, long-term objectives of "no net GHG emissions into the atmosphere" by 2050 and "a vehicle fleet independent of fossil fuels" by 2030 (OECD 2014). These demanding targets will have to be hit despite many of the cheapest mitigation measures having already been taken. Hence, on the one hand, Swedish firms have already adapted to a regime of ever more stringent climate-change mitigation policies and have decoupled emissions and economic activity more than have producers in most OECD countries, thanks to past policies. But, on the other hand, subsequent domestic mitigation measures are likely to be costlier at the margin. Analyses of mitigation scenarios that have distinguished between broad regions of the world have suggested that a disproportionate share of low-cost mitigation opportunities lie in developing countries (IPCC 2014a). The size of the extra cost burden on Sweden will depend on the extent to which Swedish climate mitigation policy will allow credit for the purchase of emission reductions made outside its borders.

Sweden also faces macroeconomic risk deriving from the pressures that the low-carbon transition will place on some other countries. The large falls in fossil fuel prices (net of any carbon pricing element) that stringent mitigation is likely to bring about will have adverse effects on current fossil-fuel exporters via their terms of trade, while fossil-fuel trade volumes are also likely to fall. The impact is likely to be particularly severe for Russia and the Middle East (EBRD 2011; Massetti & Tavoni 2011; Aboumahboub et al. 2014). Norway is also likely to be adversely affected, as the oil and gas sector constitutes around 22% of Norwegian GDP and 67% of Norwegian exports. Flows of 'climate finance' to assist mitigation and adaptation in developing countries may also have disruptive macroeconomic effects if they reach the scale necessary to finance climate-related incremental investment needs (Bowen et al. 2014). It is difficult to gauge the likelihood of feedbacks to Sweden from economic disruption in any of these countries but one metric that may be of use is the share of key countries in Sweden's trade (Table 5). Norway and Russia appear to be the major potential sources of trade disruption.

Table 5. Importance of major fossil-fuel exporters in Sweden's trade

Country	*Net energy exports/total primary energy supply %, 2013*	*(Imports + exports)/ (Total Swedish imports + exports) %, 2014*
Norway	483.4	9.30
Australia	162.4	0.57
Russia	81.1	3.40
Canada	72.9	0.46
Nigeria	91.0	0.61
Saudi Arabia	218.4	0.54
For reference:		
UK	-49.5	6.60
USA	-14.1	4.42

Source: IEA (http://www.iea.org/statistics/statisticssearch/) and UN Comtrade

4. The relevance of climate risk and carbon risk to financial regulators

4.1. Introduction

Climate risk and carbon risk can each affect the assets and liabilities of financial institutions. These two classes of risks are negatively correlated, but both may be underestimated at present. Both are subject to evolving uncertainties about the state of the world and about the responses of policy-makers over time. The implications of this are explored further below. But why should this be relevant to financial regulators? Are these risks different in some way from the other risks that financial institutions have to manage as part of their core activities of wealth management, risk management, financial intermediation and monitoring of corporate activities?

First, financial regulators need to ensure that banks hold sufficient capital and liquidity to withstand shocks to their balance sheets and income flows. Thus if climate risk and carbon risk are quantitatively important, regulators need to ensure that these risks are being appraised properly by supervised institutions. In general, banks may choose levels of capital and liquidity that are too low, ignoring the social costs of disruptions to financial intermediation and means of payment. Managers of financial institutions may engage in excessively risky strategies because they do not share in the downside risks to equity holders or bond holders (the threat that managers of failing institutions may 'gamble for resurrection' is an extreme example). These features of the financial sector provide a rationale for financial supervision. Given these possible misalignments of incentives, managers of financial institutions may also have an incentive to give too low a weight to types of risk unmonitored by their supervisors. Hence regulators must keep abreast of emerging risks such as climate risk and carbon risk if they are to ensure that they have a proper understanding of the overall riskiness of supervised institutions' lines of business.

Second, market prices may not be set in competitive markets with full arbitrage opportunities, and therefore may not reflect all information available to market participants. For example, prices may not reflect all information about the long term because potential arbitrageurs do not have sufficient capital to build up and hold contrarian positions and may be worried about the risks to their arbitrage strategies from episodes of impairment of market liquidity (Shleifer & Vishny 1990; Shleifer & Vishny 1997; Shleifer & Vishny 2011).

Third, by virtue of their links with other policy-makers, regulators may be in a better position to identify best practice in appraising emerging types of risk, especially when the risks arise from uncertainty about future policy settings. They are also likely to have a stronger incentive than individual financial institutions to disseminate new knowledge about emerging types of risk to all supervised institutions.

Fourth, policy-makers can co-ordinate collective action to correct adverse externalities, to benefit fully from benign externalities and to manage systemic risks that individual financial institutions have no incentive to act upon. Schoenmaker et al. (2015) ask the question, should macroprudential policies therefore target the management of environmental risks that are building up outside the financial system itself, at least in so far as they impinge on financial sector institutions? This would be contrary to what the authors call the 'build financial resilience' approach to macroprudential policy, where the focus is on making the financial system more robust to any and all risks, so that it can survive shocks even if they come from unexpected quarters (e.g. Borio, 2014). However, they point out that macroprudential supervisors do sometimes intervene to regulate financial institutions' relations with particular markets, particularly the real estate and construction markets. Limits on loan-to-value ratios and loan-income multiples have become more popular since the global financial crisis of 2007-08. They are designed to guard against the misallocation of real resources and to reduce the amplitude of credit cycles, which have often been associated with sharp movements in property prices (Gersbach & Rochet 2014). On this view, it is an empirical question whether other sectors of the economy merit specific interventions of this sort. Schoenmaker et al. argue that high-carbon sectors of the economy share some of the key characteristics of sectors prone to triggering financial crises: they are capital-intensive (e.g. aluminium smelters); they use relatively long-lived assets (e.g. electricity generation); they are a significant portion of the economy (carbon-intensive sectors account for about 11% of Swedish GDP[ii]); and they are largely debt-financed (the high-carbon companies to which EU financial institutions are exposed via equity, bonds and bank lending are 62% financed by bonds and bank lending, according to Weyzig et al., 2014).

4.2. Possible impact on banks' credit assets and investors' market assets from climate risk

Section 2 set out evidence on the economic impact of climate change. This evidence suggests that climate change will indeed have an impact on output and growth, and that this impact might be especially large in the tail of the distribution, i.e. there may be a low probability of a catastrophic scenario for economic performance. Since the value of financial assets is ultimately premised on the future returns to economic activities, it follows that there should also be an impact on asset values.

Despite the fact that the link between economic and financial effects is intuitively obvious, there is a paucity of peer-reviewed academic research in this area (Arent et al. 2014), especially relative to work on stranded fossil-fuel assets. Nonetheless, a few industry reports are beginning to appear and we will discuss them here.

There have been one or two industry reports that consider the implications of climate change for the optimal portfolio allocation of institutional investors, e.g. pension funds and sovereign wealth funds (Mercer 2011; Mercer 2015). Swedish pension funds including AP1 and AP4 have participated in these reports. It is best to regard such research as being in its infancy, and the robustness of the analysis is yet to be demonstrated.

Nonetheless, there is a logic to the results of such analysis, at least qualitatively. The most recent report by Mercer (2015) suggests that, at the level of asset classes, climate risk might be significant for commodities (specifically agriculture and timber), and it might also be worthy of attention for real estate, infrastructure and emerging market global equity (on the grounds that emerging market economies are relatively more vulnerable to climate change, in general). Mercer also argues that the impacts on asset values and returns are likely to be more divergent and significant at levels beneath asset classes, i.e. industry sectors and sub-sectors. In general, since climate risks are seen to be larger in some asset classes and industries than in others, a climate resilient investment portfolio would comprise different holdings of various assets and asset classes than the counterfactual.

A recent report by the Economist Intelligence Unit (EIU 2015) provides the first estimates of today's Value at Risk (VaR) to global financial assets from climate change over the 21st century. In view of the shortage of evidence, one way to obtain an estimate of climate risk to Swedish investors' assets is to consider the approach taken in this report, and how its global estimates might scale down to the Swedish case. Let us first outline the method in more detail.

Financial assets are valued at their discounted cash flow over the 21st century. While this is a long time-horizon, private-sector discount rates are sufficient to place low weight on cash flows many decades from now. Assuming corporate earnings grow at roughly the same rate as the economy in the long run, and that these earnings will ultimately accrue to asset owners, it can be assumed that cash flows also grow at the same rate as the economy.

Consequently the relative impact of climate change on economic growth (i.e. the growth rate along a climate-change scenario, compared with a counterfactual scenario in which there is no climate change) is also the impact of climate change on the relative growth of the (undiscounted) cash flow from holding an asset. Once discounted, an estimate of the present value of assets and how they are affected by climate change is obtained. Evidently this approach requires the assumption that long-term climate risk is not currently priced into financial markets, which seems appropriate given evidence on low levels of awareness within the industry (Economist Intelligence Unit 2015).

Table 6 presents some results from this approach. As can be seen, the expected or mean VaR is 2.9% along a so-called business-as-usual scenario for global greenhouse gas emissions, which corresponds with roughly 2.5°C expected warming by 2100. However, if warming instead reaches 5°C or even 6°C by 2100, which is possible under the business-as-usual scenario because of uncertainty about factors such as climate sensitivity to greenhouse gas emissions, the VaR is much higher. The higher VaR can be interpreted as the financial loss if the realised temperature increase under business as usual turns out to be in the upper tail of the ex ante probability distribution for the temperature increase. If instead of following the business-as-usual path, carbon emissions are controlled such that the expected increase in the global average temperature stays within 2°C, the mean VaR is only 1.5%. (The realised temperature increase could still turn out to be higher than 2°C, in which case the VaR would turn out to be from the upper tail of the ex ante distribution of possible losses.)

Table 6. VaR to global financial assets from climate change

Emissions scenario	*Mean*	*5°C warming*	*6°C warming*
BAU	2.94%	5%	9.65%
Expected 2°C	1.47%	..	..

Source: Economist Intelligence Unit (2015)

There are two key features of these estimates. The first is the skewed nature of the distribution of VaR, and the very large numbers in the tail. Moreover, reducing carbon emissions is particularly helpful in reducing tail risk. The second is that the estimates look similar to estimates of the present value of global economic impacts, except that they are in general somewhat lower, because private sector discount rates are substantially above those appropriate for the public sector.

Mean VaR values are considerably lower than the standard deviation of annual stock market movements (which has been of the order of 20% for the Dow Jones Industrial Index). However, it can be argued that stock markets suffer from excess volatility, so increases in climate risk could trigger larger stock price movements than the VaR numbers suggest (Shiller 1981). The risk is likely to be difficult to hedge fully given the global incidence of adverse climate change impacts and the potentially long holding periods that would be required (CISL 2015). The nature of climate risk is such that, if it crystallises, there would be no subsequent reversion to the previous trend growth path. Also, the method of estimating climate VaR assumes that credit instruments will be affected as well as equities, and it does not include the full effect of extreme weather on short-run volatility in economic performance. Mean VaR values will also be higher if sharp asset revaluations trigger macroeconomic recessions (as they do in the 'no mitigation' scenario in CISL, 2015).

How can these estimates be related to Sweden? In the absence of any more specific evidence, we might start by assuming that the VaR to assets owned by Swedish banks and investors is the same in relative terms as the VaR to global assets, just as in Table 6. Then we can ask whether there is any evidence to suggest that the VaR to Swedish-owned assets is systematically lower or higher than this. In fact, the research presented in Section 2 suggests that it should be systematically lower. That is because, first, climate change is expected to impact economic growth less in Sweden than elsewhere, and, second, because Swedish investors naturally hold a disproportionate share of Swedish assets.

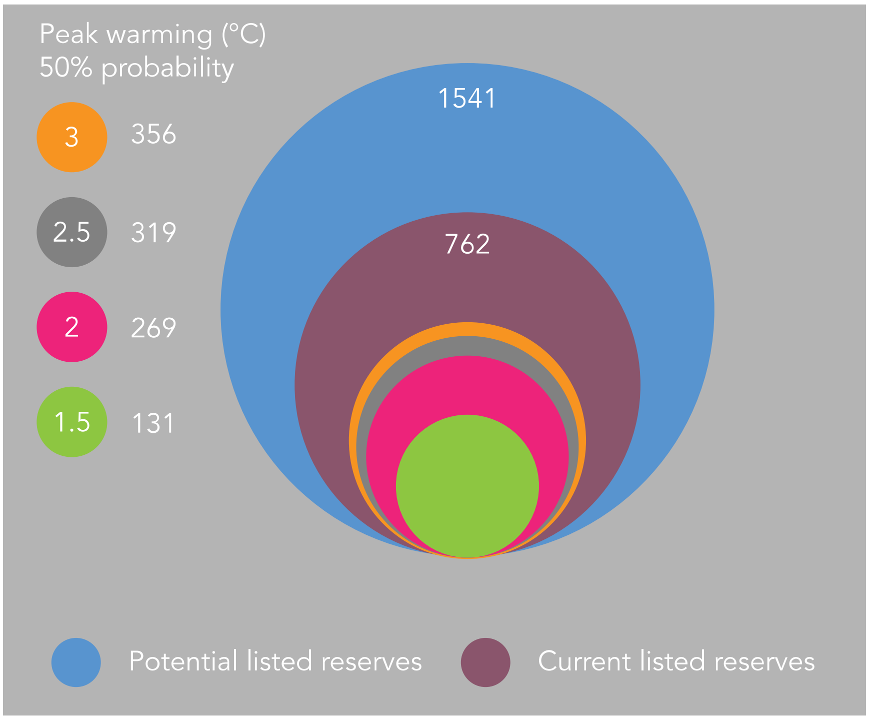
4.3. Stranded assets and 'unburnable carbon'

'Stranded assets' are assets that have suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities (Caldecott et al. 2014). Stranding can be caused by the crystallisation of risks, changes in perceptions of risks, and changes in risk aversion. Caldecott et al. argue that "Environment-related factors are already stranding assets in different sectors of the economy. This trend looks to be accelerating, which could represent a major discontinuity, able to profoundly alter asset values across the global economy." Analysis by the Stranded Assets Programme at the University of Oxford suggests that there are several environment-related risks that are poorly understood, including by agents in financial markets and credit institutions. Some of these risks are directly related to environmental threats, such as water scarcity. Others reflect the outlook for environmental policy, for example, the chances that governments around the world will take actions consistent with limiting global warming to 2°C. Assets exposed to these risks may be regularly mispriced because of the lack of understanding of the underlying environmental factors or of the implications of policy positions, resulting in an over-exposure to environmentally unsustainable assets throughout our financial and economic systems. The implications for risk depend on the size of these assets, the extent of mis-pricing, and the prospects for a sudden re-pricing.

As far as the size of the potential stock of stranded assets is concerned, most attention has been paid to the possibility that a large proportion of the reserves of fossil fuels around the world cannot be burnt if policy-makers' targets are to be respected. Carbon Tracker/GRI (2013) examined the cumulative carbon budgets consistent with various probabilities of keeping global warming to 2°C or less and compared those budgets with the carbon content of the existing reserves of fossil fuels. A 50% probability of keeping global warming to 2°C or less, given their assumptions about non-CO_2 greenhouse gases (such as methane) and aerosols that also contribute to global warming, would allow a carbon budget of 1075 Gt CO_2 to be used between 2013 and 2049 and 475 Gt CO_2 between 2050 and 2100. To achieve an 80% probability would require lower carbon budgets, of 900 Gt CO_2 and 75 Gt CO_2 respectively. According to the IEA World Energy Outlook 2012, total (known?) coal, gas and oil reserves, including state-owned assets, are equivalent to 2860GtCO_2. If these were all burnt by 2100, global warming would be likely to exceed 3°C. On this basis, nearly 50% (by carbon content) of these reserves cannot be burnt if there is to be a 50% probability of keeping global warming to 2°C or less.

Fossil fuel reserves owned by listed companies amount to around one quarter of the total; their reserves could double if all prospective reserves are developed. If listed fossil fuel companies are given a pro-rata allocation of the global carbon budget, Carbon Tracker/GRI calculated that 60-80% of coal, oil and gas reserves of listed firms are unburnable before 2050. Plausible scenarios for the successful introduction of carbon capture and storage at scale would make only a small difference. Carbon Tracker estimated that the market value of the 200 listed companies with the largest fossil fuel reserves totalled around US$4 trillion at the end of 2012, while their debt amounted to US$1.5 trillion. 16% reflected coal activities and 84% oil and gas activities. They reported analysis from HSBC suggesting that equity valuations could be reduced by 40-60% in a low carbon emissions scenario, using standard valuation methods. This would affect the New York, London and Moscow stock markets particularly, given the importance of oil companies' stock in the first and third, and coal companies' stock in the second. Similarly, credit ratings could also be impaired. Figure 9 gives a graphic illustration of the mismatch between listed reserves and the listed sector's carbon budgets for different global warming scenarios.

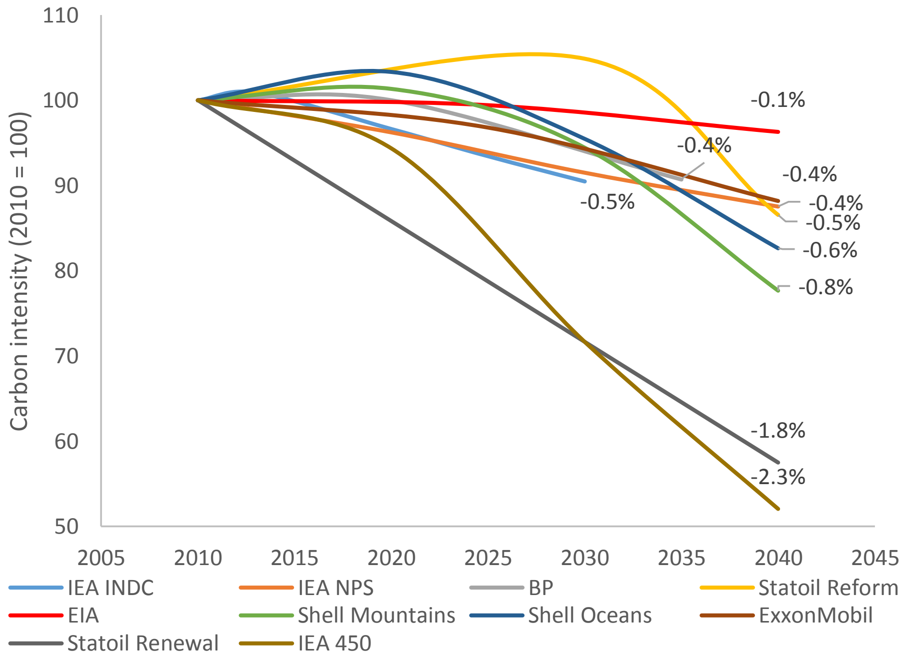
Figure 9. Reserves versus carbon budgets for different global warming scenarios



Source: Carbon Tracker/GRI, 2013

While such estimates are subject to considerable uncertainty, banks and credit rating agencies are exploring the issue further. The possibility that fossil fuel companies and other analysts have not yet fully taken on board the risk of unburnable reserves is suggested by two factors. First, a review of the types of scenarios used by analysts in major risk assessment argues that the scenarios used do not have appropriate coverage of environment-related factors, sufficient granularity and specificity about the related risks, a sound quantitative foundation or time horizons relevant to the end-user (Caldecott et al. 2014). Second, scenarios used by fossil fuel companies may be erring on the side of optimism about the prospects for their businesses in a carbon-constrained world (Carbon Tracker 2015). This is illustrated in Figure 10 below, which shows the implications of various long-term planning scenarios from official bodies (IEA, US EIA) and oil companies (BP, Shell, ExxonMobil, Statoil) for the carbon intensity of energy. The Statoil Renewal and IEA450 scenarios are consistent with strong emissions reductions but are outliers with respect to their projections for the carbon content of future energy supply.

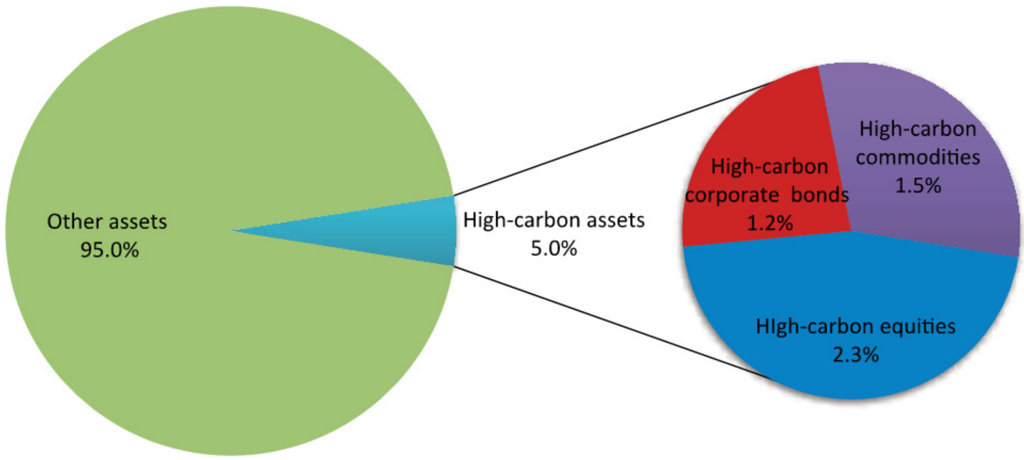
Figure 10. Implied carbon intensity of energy in different energy scenarios



Source: Carbon Tracker (2015), Figure 4.3

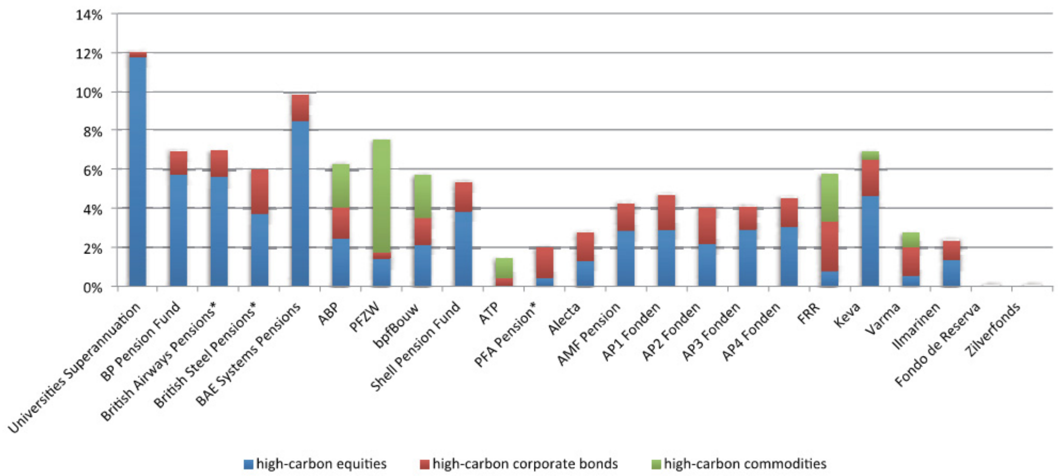
The stock exchanges of Russia, USA, UK and China together account for nearly 80% of listed fossil fuel reserves (Carbon Tracker 2012). Other countries' financial institutions are exposed to the potential stranding of assets through ownership of equity traded on these exchanges and credit exposures to the listed companies. Hence Swedish institutions may face stranded asset risk even though the Stockholm stock exchange accounts for only a tiny fraction (0.06%) of fossil fuel reserves. Weyzig et al. (2014) calculate that "equity, bond and credit exposures of EU financial institutions to firms holding fossil fuel reserves and to fossil fuel commodities are substantial. The total estimated exposures are approximately €260-330 billion for EU pension funds, €460-480 billion for banks and €300-400 billion for insurance companies." Hence "The estimated exposures are approximately 5% of total assets for pension funds, 4% for insurance companies and 1.4% for banks." These estimates require a number of assumptions about the distribution of exposures but give some guide as to the magnitude of the problem.[iii] The pension fund exposures are broken down between asset classes as shown in figure 11.

Figure 11. Estimated share of high-carbon assets in sample of EU pension funds



Swedish pension funds accounted for about 18% of the assets of the EU pension funds that could be included in the exercise. They tended to have a lower-than-average exposure to high-carbon assets (Figure 12; the Swedish funds are Alecta, AMF Pension, AP1 Fonden, AP2 Fonden, AP3 Fonden and AP4 Fonden).

Figure 12. Share of high-carbon investments in total assets, 2012

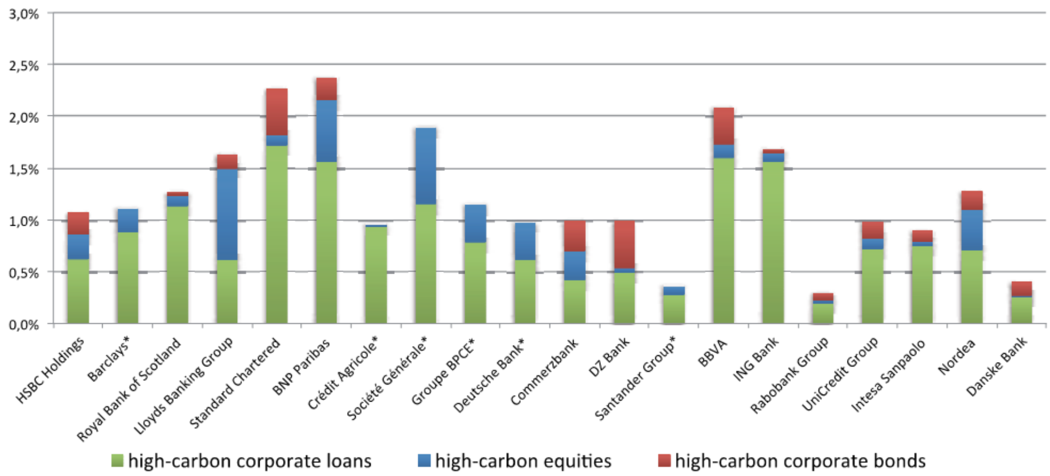


Source: Weyzig et al. (2014), Figure 4.

Note: AMF Pension states in its annual report that 5% of listed equities are in oil and gas and 9% in basic materials. These percentages are higher than Weyzig et al.'s estimates, which are based on limited coverage in Thomson ONE; thus Weyzig et al. used an estimate of 5% oil and gas and 3% coal (part of 'basic materials'), for AMF Pension.

The banks that are lead arrangers for syndicated loans to high-carbon companies, also providing a large share of the lending – the 'book runners' – are more exposed to carbon risk. The largest Swedish bank, Nordea, is not amongst the world's top 25 book-runners. However, according to these estimates, it has a relatively high exposure to high-carbon loans, equities and bonds. But much more information is needed about exposures across financial institutions to be very confident of rank orderings of institutions by carbon risk exposure.

Figure 13. Combined exposure to high-carbon assets as share of total assets, end-2012



** = Excluding corporate bonds due to lack of available data*

Source: Weyzig et al. (2014), Figure 15.

These estimates for EU exposures do not suggest that the EU as a whole or Sweden in particular are highly vulnerable to a sharp fall in the value of high-carbon companies. But the aggregate global risks to high-carbon borrowers do suggest that 'stress tests' focused on carbon risk may be warranted and investment managers should assess the risks in their own portfolios. Stress tests are analyses of what would happen to financial institutions' balance sheets and liquidity under various adverse economic scenarios. Such tests are designed to identify weak spots in financial systems at an early stage, so that preventive action can be taken by regulators and the financial institutions themselves. Weyzig et al. (2014) perform an informal stress test by considering a 'low-carbon breakthrough' scenario in which the value of equity investments in oil, gas and coal businesses falls by 60%; the value of fossil fuel commodity investments falls by 50%; the value of the long-term bonds of oil, gas and coal businesses falls by 30%; losses on the project financing of individual oil, gas and coal projects are 30%; losses on term financing provided to oil, gas and coal projects are 30%; losses on revolving and stand-by credit facilities to oil, gas and coal projects are 20%; and losses on other loans to oil, gas and coal projects are 5%. (A low-carbon breakthrough is likely at the same time to boost the value of investments in companies exploiting new low-carbon technologies, some of which are likely to be forms currently focused on exploitation of fossil fuels.) The stress test finds that

> "risks to financial stability at the EU level as a whole are limited, but risks to some individual financial institutions are large. This means that greater attention must be given to the management and mitigation of carbon bubble risks in order to prevent large concentrated losses at systemically important financial institutions in the EU."

Swedish institutions are not among those picked out for special concern in this regard (the UK and France are flagged as facing greater challenges), but would benefit from considering the carbon risk facing some of their financial counterparties.

This stress test is predicated on a sudden change in the outlook for fossil fuel use. However, some possibility of a decline in the demand for fossil fuels is probably already reflected in asset prices, given the ongoing global debate on the need for worldwide collective action to halt manmade climate change. The change in outlook may come about gradually, for example, as innovation brings down the costs of low-carbon technologies. Changes in the policy environment may be more abrupt and therefore stressinducing. But financial institutions may remain sceptical about the prospects for a rapid transition to a low-carbon global economy, even given the strong government commitments to 'intended nationally determined contributions' under the UNFCCC process. For example, they may note the lack of consistency in policies across individual government departments, particularly with respect to energy supply decisions. Climate Action Tracker (2015) notes that, "if all coal plants in the pipeline were to be built, by 2030, emissions from coal power would be 400% higher than what is consistent with a 2°C pathway… Even with no new construction, in 2030, emissions from coal-fired power generation would still be more than 150% higher than what is consistent with holding warming below 2°C." The prospect of successful climate-change mitigation policies may simply encourage fossil-fuel companies to exploit their resources faster, so that policy-makers may not be able to ensure that 'unburnable carbon' is kept in the ground. In this eventuality, fossil fuel prices may fall sharply when new policies are announced but estimates of the proportion of high-carbon assets that will be stranded would be inaccurate. The 'stranded assets' argument also depends on the assumptions that alternative energy supplies will be available in time and at a low enough cost to make a low-carbon transition feasible and that CCS will not be available on a large scale (Butler, Financial Times, 28 September 2015). Both these assumptions seem plausible in the context of a stress test of downside risks to high-carbon companies but, as with uncertainty about policy-makers' commitment to the 2°C ceiling, may raise doubts among financial institutions about whether the Carbon Tracker stranded assets scenario should be seen as a central case.

More generally, as Helm (2015) argues, high-carbon assets are continually affected by uncertainty and news about fossil fuel prices, arising not just from the climate-change policy outlook but also technological innovations such as fracking, supply uncertainties such as OPEC members' responses to low oil prices, and demand uncertainties such as the pace of Chinese growth in the near term. Oil price falls are already included in many stress test scenarios. In this sense, the 'stranded assets' argument merely reinforces the view that stress tests should envisage the possibility of sharp downward fossil fuel price adjustments. Nevertheless, carbon risk is a relatively new source of such adjustments and warrants further investigation by portfolio managers. It is a matter of concern that, worldwide, just 7% of investment funds rated by the Asset Owners Disclosure Project calculate portfolio emissions, and only 4% both assess potential stranded assets in their fossil fuel holdings and take clear action to mitigate these risks (AODD 2015).

An investing institution would be able to hedge some uncertainty about the pace of mitigation by holding both assets exposed to carbon risk and assets exposed to climate risk, given that more rapid mitigation means more of the former and less of the latter. But if markets do not currently adequately reflect the climate risks under business as usual, or if scientific developments were to lead to upward revisions of estimates of climate risk, such a strategy would not fully protect investors.

4.4. Carbon market instruments

Climate change mitigation in practice is carried out with a wide variety of policy tools. Some of these tools entail the creation of new types of financial transaction and financial assets, which may require a regulatory response. One example is the EU Emissions Trading System (ETS), in which the relatively novel instrument of an emissions allowance or credit is traded. This has been subject to VAT fraud in the past; a 'carousel' fraud involving the trade of emissions credits in 2008 and 2009 led to a loss of €5 billion in national tax revenues. The European Court of Auditors (2015) concluded that the management of the EU ETS by the Commission and Member States has not been adequate in all respects. It had been "hindered by certain issues related to the robustness of the framework for protecting its integrity, and by significant weaknesses in the implementation of phase II of the EU ETS." The Court concluded that "[t]here are remaining issues regarding the regulation and oversight of the emission market related to compliance traders, bilateral over-the-counter spot trading and smaller market participants; there is no EU level oversight of the emissions market, and there is insufficient regulatory cooperation; the legal definition of emission allowances is not sufficiently clear and there is also a lack of clarity regarding the creation and protection of security interests in allowances; and The Union Registry [which processes EU ETS data]… has a high risk profile due to the financial stakes and wide range of account holders." There have also been problems with the Clean Development Mechanism (CDM) of the United Nations, which allows advanced industrial countries subject to the UNFCCC Kyoto Protocol to buy 'Certified Emission Reduction' units to contribute toward their emission reduction obligations; opportunities for fraud have arisen with respect to the additionality of CDM emissions reductions (Drew & Drew 2010).

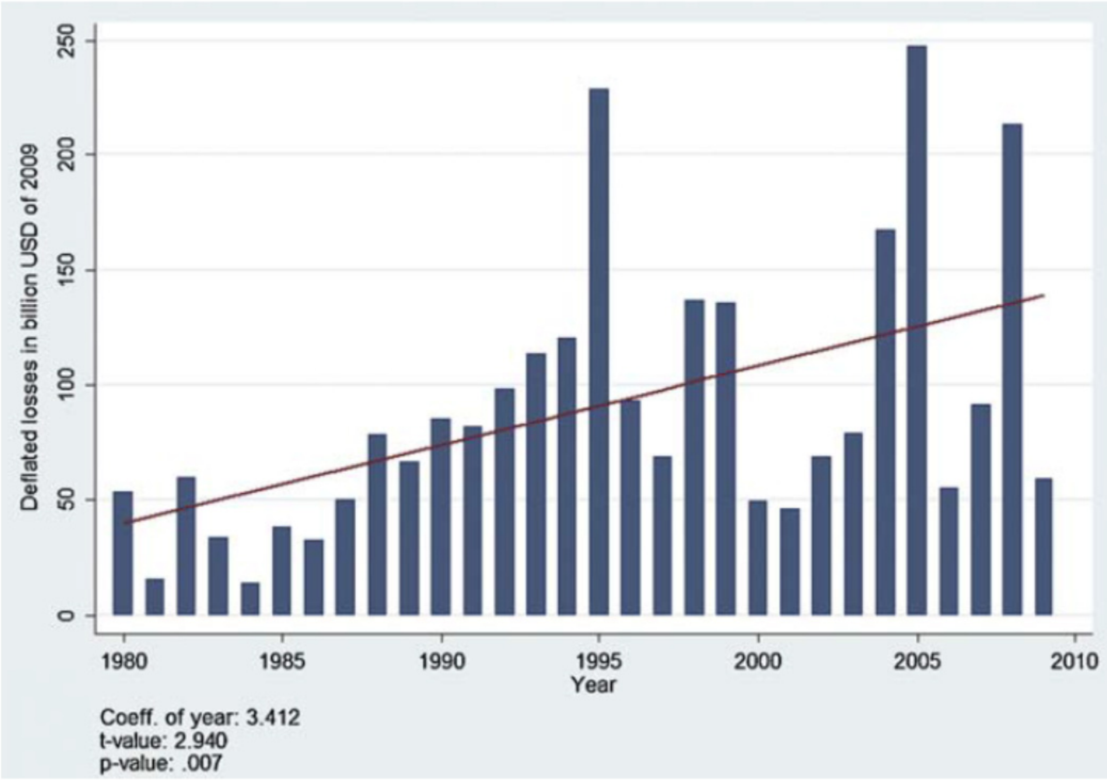
As more countries experiment with emission trading systems and private markets in emissions reductions multiply, regulators will have to pay more attention to risks associated with the financial assets created.

4.5. Exposure of insurers to climate and liability risk

This section describes climate risk to the liability side of general insurers' balance sheets. Several perils that are commonly insured are due to, or can be indirectly caused by, extreme weather. These include the direct effects of extreme weather, such as property damage from coastal or river flooding, or from windstorms, as well as indirect effects, such as business interruption due to the direct effects of extreme weather elsewhere, transmitted to an insured company along the supply/value chain (the Thai floods of 2011 are a prominent example of this).

Global insured losses due to extreme weather events are on a long-term and statistically significant increasing trend (Figure 14). Up until now, this appears largely attributable to an increase in the value of insured assets (i.e. exposure), although when long time series are analysed for the United States and West Germany (where they are available), a statistically significant effect from climate change itself starts to emerge (Neumayer & Barthel 2011; Barthel & Neumayer 2012). Other recent evidence also points to the emerging effect of climate change on insured losses (Prudential Regulation Authority 2015). In any case, there are sound reasons to suppose that the climate-change signal will get stronger in the future.

Figure 14. Global annual insured losses (in real terms) from extreme weather events between 1980 and 2009



Source: Munich Re's NatCatSERVICE database (Neumayer & Barthel 2011)

If climate change results in an increased frequency of extreme weather, then expected liabilities for affected general insurers (Average Annual Losses) should rise, as should the risk of an especially large loss, such as those for many US and worldwide insurers following Hurricanes Andrew in 1992 and Katrina in 2005. These impacts on insurers' liabilities imply changes in premium rates and risk-bearing capital in order to remain profitable and able to honour contracts respectively. Many insurers are well aware of the risk to their liabilities from climate change, and have been important in generating the research base over the last several decades.

As the recent Bank of England Prudential Regulation Authority report on climate change and insurance in the UK (PRA, 2015) explains, the vulnerability of general insurers to climate risk depends on several factors, notably:

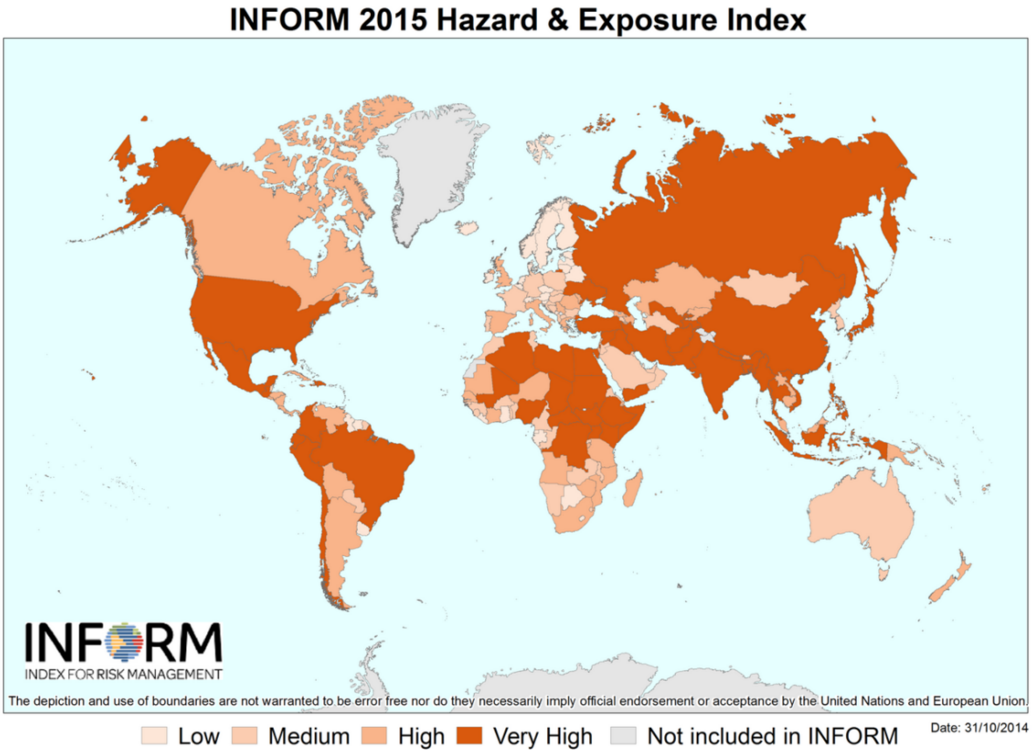
- The accuracy of catastrophe model forecasts;
- The extent of risk management through portfolio diversification and risk transfer (e.g. reinsurance and catastrophe bonds);
- The length of insurance contracts and the amount of risk-based capital held.

Appropriate use of all of these tools leads, in the PRA's view, to general insurers in the UK being "reasonably well equipped to manage the *current* level of direct physical risks" (our emphasis). They are more concerned with the implications of climate risk in the long run, including for the affordability of insurance, and the correlation of risks. They also highlight the role of government in insurance markets, which can be both positive and negative depending on the nature of the intervention.

It is also possible to conceive of climate risk to the liabilities of life insurers, through its effect on morbidity and mortality, although, as the Prudential Regulation Authority (2015) recently pointed out, this source of risk is likely to be small relative to other risks to life insurers' underwriting, certainly in the short run.

At the country level, the extent of risk is going to depend on particular features of that country, notably the prevalence of extreme weather, features of the insurance market, and how risk is managed by insurers. As Figure 15 and Figure 16 show, while natural hazards such as flooding do occur in Sweden, they are less common than in most other parts of the world. Figure 15 puts Sweden in a global context by mapping the prevalence of natural hazards globally according to the ‘INFORM’ index, which ranks countries on a scale from low to very high exposure. INFORM is a collaboration of various international agencies. Sweden is in the lowest category. It faces lower hazard exposure than, for instance, the UK, France, Germany and the USA.

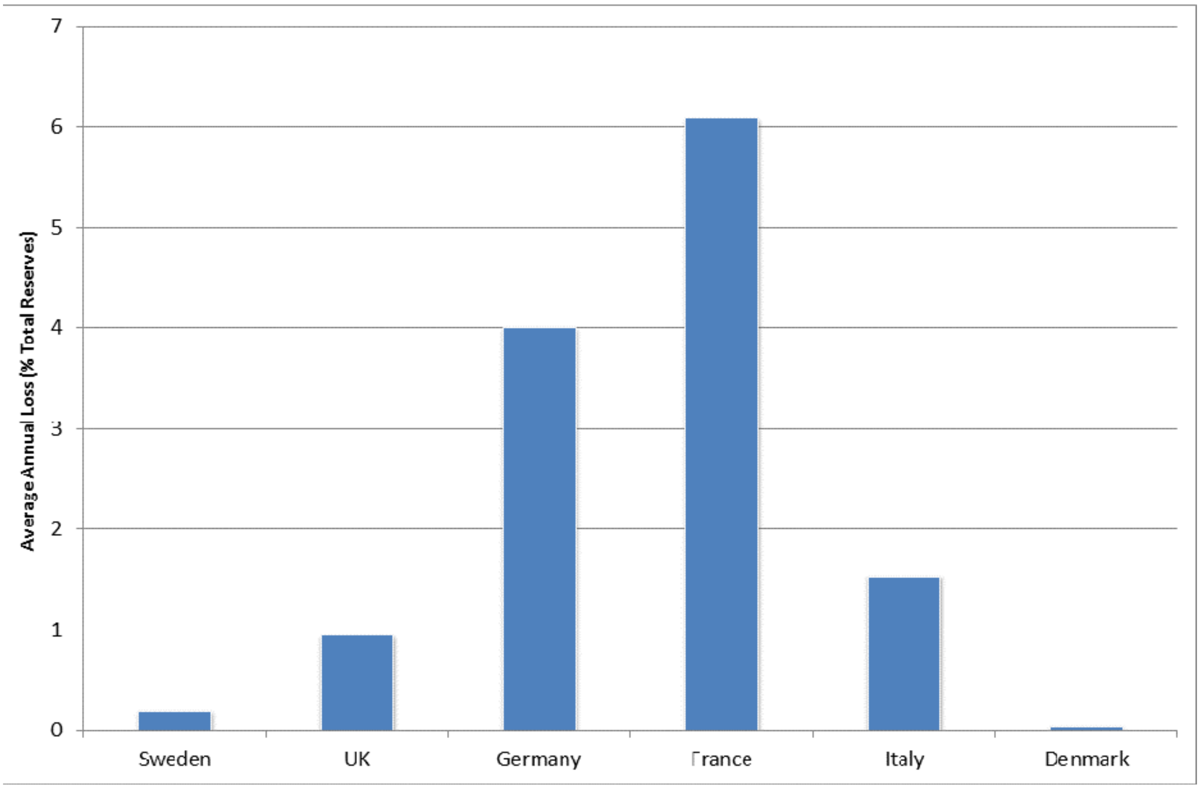
Figure 15. Global natural hazard prevalence according to the INFORM index



Source: http://www.inform-index.org

Figure 16 presents data more specific to insurance. It compares Sweden with a handful of other European insurance markets, in terms of Average Annual Losses (AALs) from flooding, expressed as a percentage of total insurer reserves. These data are based on catastrophe-risk modelling rather than historical experience. Flooding is the principal source of insured losses from extreme weather in Europe. Insured losses due to wind and coastal surge are negligible in relative terms in all these countries, with earthquakes being the only other material source of risk. As Figure 16 shows, Sweden faces relatively low AALs attributable to extreme weather.

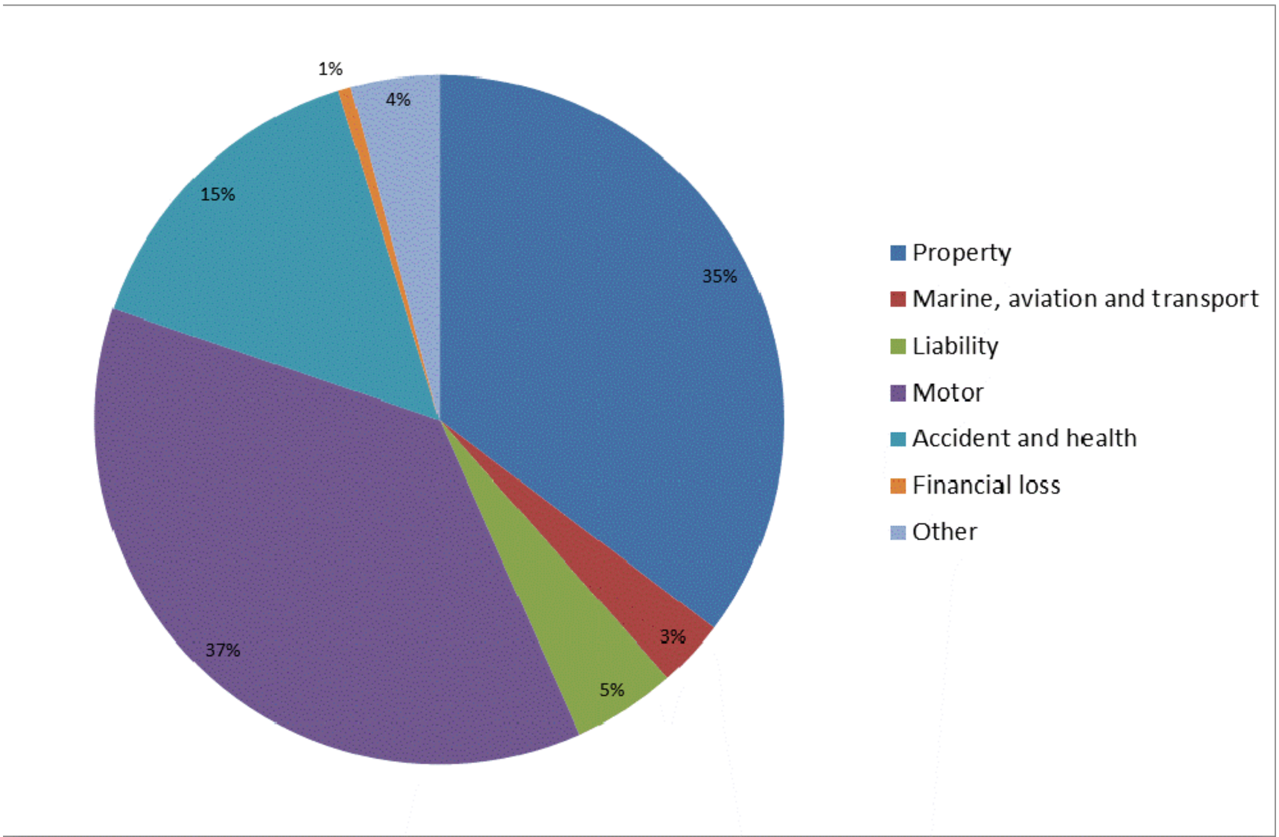
Figure 16. Modelled Average Annual Losses due to flooding in six European insurance markets



Source: UNISDR data

In terms of the features of Sweden's insurance market, a basic piece of information is the share of the total insurance market assumed by the lines of general insurance most vulnerable to climate risk, i.e. property, and marine, aviation and transport (Prudential Regulation Authority 2015). In the UK, for example, this is 38% in total, of which 24 percentage points is property and the remainder is marine, aviation and transport. As Figure 17 shows, these four groups also amount to 38% of all gross written premiums in general insurance in Sweden, with property accounting for the vast majority of that. In absolute terms, gross written premiums in property, and marine, aviation and transport amount to SEK 38 billion.

Figure 17. FI-regulated general insurance firms' gross written premiums in 2014



Source: Finansinspektionen

Beyond the share of the market, one also needs to look at the ability of the Swedish insurance industry to manage climate risk. We argue that the overall picture is similar to the UK and therefore that the conclusions drawn by the Prudential Regulation Authority, set out above, are also likely to hold here.

Two important features of this are that (a) contracts tend to be annual, so that forecast losses are relatively insensitive to long-term climate trends, and (b) the common Solvency II regulatory framework governing insurers in the EU means that risk-based capital provisioning in the two countries is similar (EIOPA, 2014). An additional point is that, with a few exceptions, public infrastructure in Sweden is not insured against extreme weather.

As well as climate and carbon/transition risks, there is the possibility that parties who suffer losses due to climate change or to the transition to a low-carbon economy could successfully hold other parties legally liable, and that insurers may need to pay out on liability policies as a consequence. In principle this is a significant risk for the insurance sector, given historical experience of very large losses from some similar forms of legal liability, such as for the health effects of asbestos. These claims would likely be pursued within the terms of existing kinds of insurance contract, such as those that limit general/public liability, liability of directors and officers, and provide professional indemnity.

Liability claims related to climate change could fall into three categories (Prudential Regulation Authority 2015):

1. Failure to mitigate – these are claims that holders of liability insurance policies are responsible for loss and damage from climate change due to a failure to reduce their greenhouse gas emissions;
2. Failure to adapt – claims that holders of liability insurance policies are responsible for losses due to a failure to adapt to the impacts of climate change or to the consequences of the transition to a low-carbon economy. This obviously includes physical loss and damage from climate change, but under this category one could also include more indirect types of claim, such as one recently made in the United States, whereby a pension fund was accused of breaching its duty of prudence in

failing to take into account the financial risks of investing in the coal industry under carbon regulation (Prudential Regulation Authority 2015);

3. Failure to disclose/comply – claims that holders of liability insurance policies failed to adequately disclose information related to their impact on climate change.

At present, there is little or no evidence of liability claims falling into these three categories being successfully pursued, certainly in the courts. From the point of view of the plaintiff there are difficult issues around attribution of losses to climate change and whether in addition losses could be reasonably foreseen. The large majority of claims have been made in the United States. However, as the Bank of England notes, this is common in the early days of liability litigation and does not necessarily mean that in the future claims will continue to be unsuccessful (Prudential Regulation Authority 2015).

According to its analysis, liability risks are currently low, but they may “evolve adversely” due to the growing effects of climate change and the increase in climate-related legislation. One crucial factor for insurers is likely to be whether policies are written on a claims-made or losses-incurred basis, with the latter being more vulnerable.

5. Some policy issues

5.1. Introduction

This section raises some policy issues for prudential regulators arising from the discussion of the exposure of financial sectors to climate risk and carbon risk. Several of them are already being discussed by public policy-makers. In each case, it is helpful for policy-makers to consider whether (i) there is a rationale for action by regulators or whether market participants can be left to assess and mitigate the relevant risks, and (ii) whether the costs of regulatory action are likely to be outweighed by the benefits, given the degree of materiality of the underlying risks.

5.2 Stress testing

The informal stress tests of climate risk and carbon risk carried out by analysts outside the financial sector have been broadly reassuring but they have identified areas of concern and drawn attention to the heterogeneity of the sector. As these analysts have much less comprehensive and accurate information about firms' balance sheets than financial regulators and the firms themselves, there is a case for regulators mandating stress tests to investigate the consequences for regulated firms of a higher frequency of extreme weather events, catastrophic climate change and the sudden 'stranding' of high-carbon companies' assets. This would ensure that the downside risks resulting from the uncertainties about climate science, impacts and efficacy of mitigation policies were explored properly. Such stress tests would clearly serve microprudential objectives but, given the global nature and potential scale of climate risk and carbon risk, they would also be useful in the context of macroprudential stress testing for financial stability.

The recent report of the Bank of England's Prudential Regulation Authority (2015) concluded that insurance firms are reasonably well equipped to manage the current level of physical risks from climate change. But they also noted that, "risks to the PRA's objectives would appear to be lower where firms are also… considering multiple perspectives on risk, including the use of stress and scenario testing." They encourage insurance firms to analyse and discuss climate risks more in the industry but stop short of insisting climate risk is included in regulatory stress tests, writing that:

> "The PRA will give further consideration as to how best to incorporate the identified climate change risk factors into its existing framework and supervisory approach. This may include, amongst other actions:
>
> (i) reviewing the PRA's business model analysis and stress-testing framework to ensure the latest view of climate change risk factors is captured;
>
> (ii) continuing to build in-house technical expertise to support supervisors in their understanding and assessment of climate change risks as they relate to insurers; and
>
> (iii) a thematic review of firm ORSAs [Own Risk and Solvency Assessments] to evaluate the extent to which climate change risk factors are being appropriately identified and assessed."

The '1-in-100 Initiative' of UNIDSR and the World Economic Forum, launched at the UN's 2014 Climate Change conference, is pledged to develop stress testing, building on insurers' existing expertise. This initiative seeks to stimulate and reward climate resilient investments and recognize sound business models, strategies and plans that generate societal and commercial co-benefits. It also seeks to strengthen the support for the development of the science and data required for analyses of risk. A consortium of partners (from finance, science and the public sector) made a commitment to invest a year in preparation and pilot application of 1-in-100-year climate risk metrics across banking and securities regulation; incorporate them within public and private accounting standards; and require reporting of these metrics on an annual basis based on the tools and experience of the insurance industry. They have been liaising with the relevant regulatory authorities and stakeholders to determine how this approach can be implemented, with an aspiration for climate and disaster risk and resilience to be fully recognised and assessed within the financial system by 2020.

As far as carbon risk is concerned, Carbon Tracker and others have argued that high-carbon firms and the financial institutions that finance them have an inadequate understanding of the risks of transitioning to a world that would respect the 2°C ceiling on global warming. The emphasis has been on advocating stress testing by these economic agents themselves. However, regulators may wish to consider the argument made by Schoenmaker et al. (2015) that carbon risk has some similarities with risks from the housing market and may, therefore, merit inclusion in some macroprudential stress test scenarios. One step in this direction would be to calibrate shocks to fossil fuel prices in such scenarios to the size of shocks that could arise from a sudden increase in the credibility of commitments to keep below the 2°C ceiling. The work of Weyzig et al. (2014) suggests a way of calibrating the shocks and could form a template for regulators' own work in this area. Together, European regulators would be able to improve on their estimates, given their access to supervisory data. The Canfin-Grandjean Commission (2015) suggested that the Bank for International Settlements (Basel Committee) should define methods to include climate risks in stress tests for banks and insurance companies.

5.3 Carbon disclosure

Stress testing for carbon risk requires information about carbon exposures. Governor Carney of the Bank of England has made the case for developing consistent, comparable, reliable, efficient and clear carbon disclosure standards (Carney 2015). Disclosures abound but have not been systematised in a single widely accepted format. Carney noted that there are already nearly 400 initiatives to provide such information, so that there is a danger of getting "lost in the right direction." The international Financial Stability Board (FSB) published in November 2015 a proposal to the G20 for the creation of an industry-led disclosure task force on climate-related risks, suggesting that it could be modelled on the example of the FSB's Enhanced Disclosure Task Force, in order to "develop voluntary, consistent climate-related disclosures of the sort that would be useful to lenders, insurers, investors and other stakeholders in understanding material risks." This is an initiative that FI and other Nordic regulators may wish to follow closely, for example, by assessing whether it will cover assessment of firms' claims to be low carbon and therefore low risk.

5.4 Fiduciary duties of managers of firms

A number of campaigns have developed around the world to promote divestment from high-carbon assets. On one view, this is simply good economic sense given the prospects for these assets in a carbon-constrained world. On another view, divestment can act as a way of pressing firms to adopt strategies to reduce their carbon use, either through the glare of publicity and firm reputation or through depressing share prices. Managers of firms need to consider what attempting to maximise shareholder value means in a world of climate change given their assessment of risks, including those around current and future climate policy. This assessment would be likely to change if they risked claims for loss and damage from victims of climate-change impacts. Covington et al. (2016) argue that "clients and beneficiaries of investment firms might have a legal case to bring against their investors who stand idly by as emissions erode the value of their stock" given that climate risks to portfolios are material. In the USA, Arch Coal and Peabody Energy have been sued on the grounds that their pension plans retained Arch and Peabody stock as investment options when a reasonable fiduciary would have done otherwise, because it was clear that there was a 'sea-change' in the coal industry, in part due to climate-change policies (as reported at http://blogs.law.columbia.edu/climatechange/2015/09/10/september-2015-update-to-the-climate-litigation-chart). Some of the issues around carbon asset divestment are discussed in Ansar et al. (2013).

The campaign for the Australian National University to divest their investment portfolios of fossil-fuel-based assets stimulated a debate about the meaning of fiduciary duty in this context. Liddell (2015) argued that divestment of fossil fuel assets purely on the basis of the personal environmental beliefs of individual trustees would be a breach of fiduciary duty with the possible consequence of personal liability to trustee directors. But:

> "the best way for a trustee to exercise their fiduciary duty is to pro-actively consider the risks to their investments and to take action to manage those risks. Divesting from fossil fuels because fossil fuels companies are 'bad for the planet' would appear to breach fiduciary duty unless the trustee is able to demonstrate that the majority of fund members share the concern (and they are also able to demonstrate that the divestment would not cause material financial detriment). It breaches the Duty of Loyalty a trustee has to the core (financial) purpose of the trust. However, divesting from fossil fuels because, after active investigation and consideration the trustee took the

> view that the assets were at risk from an (inevitable) change in the policy environment is totally consistent with fiduciary duty. By giving consideration to a material risk to assets in the investment portfolio the trustee has demonstrated prudence and by acting to avoid capital losses the trustee has demonstrated their loyalty to the core purpose of the trust."

Some firms have taken the view that their fiduciary responsibilities warrant better disclosure of climate and carbon risks, consistent with the argument from the prudential risk management perspective discussed in section 5.3 above.

5.5 Regulation of carbon market instruments

The European Court of Auditors (European Court of Auditors 2015) argued that "[t]here have been significant improvements to the framework for protecting the integrity of the system, notably through the inclusion of most of the spot market for allowances under the 'markets in financial instruments' directive (MiFID) and 'market abuse' (MAD (market abuse directive)/MAR (market abuse regulation)) regimes by the qualification of emission allowances as financial instruments." It made a number of recommendations with regard to improving the integrity of the EU ETS. Although mainly directed at the European Commission, member state regulators also need to be aware of the potential for abuse, not least because financial assets deriving their value from emission reductions are likely to become more important over time.

5.6 Guidance or guarantees on the path of the carbon price

Many economists have argued that a global carbon price would be the most efficient signal to economic agents about the stringency of policy against climate change (e.g. Bowen, 2011). The Canfin-Grandjean Commission (2015), reporting to the French President, goes one step further, proposing the establishment of a 'carbon corridor' or a 'carbon target', independent of any international agreement of the UNFCCC. This 'carbon corridor' would be implemented by developed and emerging countries on a voluntary basis, and include a minimum target price of US$15 to 20/tonne of CO_2 in 2020, and a maximum target price of US$60 to 80/tonne of CO_2 in 2030/2035. However, given the difficulties of concluding international agreements in this area and the reluctance of many countries to accept advice on the detail of their Intended Nationally Determined Contributions to global emissions reductions, this proposal seems unlikely to be successful. While it would be helpful for public agencies in a country to agree and disseminate a common projection for domestic carbon prices to encourage consistent firm-level planning and consistent approaches to asset valuation, any such initiative would have to take account of the wide range of effective carbon prices in practice in many countries. In Sweden's case, firms in some sectors are already expected to pay a considerably higher carbon price than the Canfin-Grandjean suggested maximum for 2030/2035.

5.7 Standards for bank capital

Advocates of investment in new low-carbon technologies have raised the concern that the Basel capital standards discourage banks from lending to low-carbon projects because these tend to be relatively long-lived, front-loaded, complex, capital intensive and subject to political risk. One way around this problem would be to designate certain projects as 'low carbon' and allow them a lower capital weighting. Hourcade et al. (2011) have devised a scheme in which an officially sanctioned Social Cost of Carbon (SCC) (indicative carbon price) is integrated into a project's appraisal. This SCC would be used to price carbon certificates issued by the government and delivered to banks to issue credit facilities to designated low-carbon projects, reducing their risk-adjusted costs. These carbon certificates could be gradually transformed into legal reserve assets of the banks after verification of the performance of the projects. There are certain potential disadvantages of this approach. For example, it could encourage neglect of proper risk and investment appraisal in the low carbon sector. It would not in itself solve the problem of the political risk of climate policy reversals. Agreement on the appropriate figure for the SCC would be difficult (although less so if the suggestion discussed in section 5.6 were adopted). And it would raise the possibility of prudential standards being relaxed for the purposes of economic planning, with the risks still being held by the private sector.

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[i] See section on 'issues for further action', G20 communique, 17 April 2015, available at: http://www.g20.utoronto.ca/2015/150417-finance.html

[ii] The following have been counted as carbon-intensive sectors: mineral extraction; paper and paper products; coke and refined petroleum products; coke, refined petroleum, chemicals and basic pharmaceutical products; 'other' non-metallic mineral products; manufacture of basic metals; electricity, gas, steam and air conditioning supply; air transport; land transport; water transport; waste collection, materials recovery and other waste management services.

[iii] According to Weyzig et al. (2014), p.5, their analysis "estimates the exposures of 23 large EU pension funds and the 20 largest EU banks to oil, gas and coal mining firms. For equity investments and corporate loans, the analysis identifies individual shareholdings in, and syndicated loans to, approximately one thousand fossil fuel firms, using financial databases. For corporate bonds, it makes a rough estimate of the exposures of financial institutions on the basis of their general asset distribution and bond market indices. Pension fund investments in fossil fuel commodities are estimated as well. The exposures of the investigated financial institutions are then scaled up to the total EU pension sector and all EU-based banks."