

# Climate change: the role for central banks

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## Introduction

The role of the financial system in the economy and society is to facilitate the necessary financing and liquidity for human and economic activity to thrive – not only today, but also for future generations. Central banks and financial regulators play an important role in monitoring and controlling the risks that would threaten the stability of the financial system, and hence imperil the stability and sustainability of the economy. In light of the Great Financial Crisis of 2007-09 (the GFC), central banks and their functions have come under scrutiny and in some cases are developing their operations as part of broader financial regulatory reforms to make the economy “generate strong, sustainable and balanced growth” (G20 ,2009).

In this paper we consider the potential role of central banks in mitigating the risks from environmentally unsustainable economic activity, particularly that which contributes to climate change. This is a controversial matter in some countries,<sup>5</sup> partly given the many other responsibilities that central banks already have and because sustainability can itself be a contentious political issue. We argue that the potential consequences of climate change for the economy in general, and for the financial sector in particular, mean that it falls squarely within the existing mandates of central banks and their primary objectives. Beyond that, many central banks have secondary objectives to support wider government policies which could enable them to go further than currently envisaged, but without compromising their primary objectives.

The primary policy responsibility for preventing and adapting to climate change, and limiting the related financial risks, should lie squarely with governments. They are the authorities that control national legislation, tax and expenditure programmes, and make direct state interventions in the economy. And they have the overall responsibility for regulatory frameworks in the financial sector and elsewhere in the economy. Furthermore, the main agents for implementing those policies will be the private sector which generates most of the risks and has the greatest potential for addressing them.

Notwithstanding the roles of government and the private sector, we argue that the central bank must take climate change into account to the extent that it is part of their core mandate in delivering monetary and financial stability. Beyond that, there is more that they could choose to do as part of their secondary objectives – neither role should be underestimated.

Explicit secondary objectives for central banks are quite common: at least 50 of the world’s central banks have some sort of responsibility, usually expressed as secondary to their monetary policy responsibilities, to support the country’s broader economic policies (Dickau and Volz, 2019). But we note that there is no formal legal definition or even academic literature which convincingly explains how secondary objectives are meant to be interpreted.<sup>6</sup>

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<sup>5</sup> For example, Australia or the US, but not elsewhere e.g. the UK or Netherlands.

<sup>6</sup> Fisher and Grout (2017) posit an explanation and interpretation.

This paper addresses what constitutes appropriate central bank policy in respect of environmental sustainability. Sound money and sustainability both depend on finding the right balance in the economy. Central banks use monetary policy to try to balance aggregate demand and supply. When they intervene in markets they can have significant impact – either to steer the economy or to address financial instability. This gives central banks the power and opportunity – subject to mandate - to address market distortions and externalities. But in pursuing any individual objective there is a risk of creating undesirable and unintended distortions. So it is important that potential market interventions are thoroughly analysed to ensure that the benefits exceed the costs, and that the latter are correctly recognised. In the context of sustainability, we find that some policy proposals could cause more harm than benefit: just because something could be done, that doesn't necessarily make it the right thing to do.

This paper proceeds by analysing the various responsibilities of central banks: monetary stability, financial stability and micro-prudential supervision – as well as broader balance sheet and corporate responsibilities - identifying where central banks could reasonably play a role in monitoring and limiting the financial risks associated with unsustainable environmental activity. That broad framework might also be suitable for investigating the potential contribution of central banks to other policies which, at first glance, are outside of their traditional core remits.

## **1 Environmental Risks and Central Banking**

### *1.1 Environmental Risks and Financial Stability – Historical Overview*

Economic historians have demonstrated relationships between weather, agricultural markets and financial markets to show that there are linkages between natural disasters (e.g. drought) and financial market instability.<sup>7</sup> The United States suffered from dust bowls in the farm belt states in the 1880s and 1890s and again in the 1930s, because of soil erosion that occurred from unsustainable farming methods (Hornbeck, 2012). Although the United States was suffering an economic depression in the 1930s that had caused hundreds of banks to fail across the country, economists have demonstrated how some of the banking sector distress experienced in the farm belt states could have been attributed to the dustbowl phenomenon. The ensuing economic downturns during these periods resulted in substantial losses on bank loans and related financial market distress that spread, contagion-like, through the regional economy (Hornbeck, pp. 1481-3).

More recently, in the late twentieth and early twenty-first century, increased hurricane activity in the Caribbean and south eastern United States caused huge bank losses to businesses and individuals directly impacted by these high wind storms. Hurricane Andrew caused \$24 billion in damages to the south Florida economy in 1992, while hurricanes Rita, Wilma and Katrina each caused widespread and extensive damage to Caribbean economies and to the south eastern United States. Hurricane Katrina came ashore in south Florida and New Orleans in August 2005, causing in excess of \$200 billion in damages and ranks as one of the costliest natural disasters in U.S. history (see Lambert et al, 2017, p 3). The damages

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<sup>7</sup> For a review of the literature, see Landon-Lane et al. (2011) pp 73-84.

led to high loan losses and provisioning for banks that were based in the impacted areas. The bank losses led US regulators to review the adequacy of bank risk models regarding credit risk and hurricane damage.

Similarly, severe natural resource constraints (e.g. oil) can result in banking and financial market distress. The Arab oil embargo of 1973 imposed constraints on the supply of oil that led to a near tripling in its dollar price by the spring of 1974. This led to a substantial increase in the flow of petrol-dollars into the global banking system, thereby creating serious stresses in the Eurodollar and Eurocurrency markets, which contributed to the failures of several western banks (e.g. Franklin National Bank and Herstatt Bank).<sup>8</sup>

More recently, environmentally unsustainable economic activity has become a concern for central bankers and financial regulators because threats to the sustainability of the physical environment generate systemic risk for the financial sector. Scientists define the limits to sustainable human activity as the Earth's planetary boundaries – which, if breached, could generate “unacceptable environmental change for humanity” (Rockström et al., 2009). Nine planetary boundaries have been identified and quantified within which humans can continue to live and thrive into the future, but which are under increasing stress and, if breached, will impose significant costs on the global economy. Three of these boundaries (namely climate change, biological diversity and nitrogen input to the biosphere) are thought to have been crossed already.

The historic linkages between environmental sustainability and economic and financial stability raise the fundamental question of whether, and if so how, central banks and other financial regulators and policymakers should address the financial stability risks associated with environmentally unsustainable activity. Experts have long argued that such environmental sustainability risks may be amongst the biggest risks that the world faces today.<sup>9</sup> The biggest social challenges may arise from gradual failures or creeping risks that are linked to dramatic changes in global population growth, ageing and the ensuing rise in consumption, all of which have implications for resources, climate change, health and fiscal policy. Climate change is the boundary about which we know the most; the International Panel on Climate Change (IPCC) has documented the scientific evidence in support of the proposition that carbon-intensive activities lead in the longer-term to global warming, rising sea levels and ocean acidification, while in the shorter term they can lead to increasingly volatile weather patterns, including extreme temperatures and intensified flooding of coastal and low-lying areas, water shortages, and the health costs of pollution. (See IPCC 2007; 2013; 2014a; 2014b; 2014c; 2014d; 2018).

The scale of the economic impact of such risks and of the economic transformation required to address them is significant. A study by the United Nations estimates that the annual cost to the global economy of maintaining the current scale of unsustainable economic activity

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<sup>8</sup> See Goodhart (2011), p 37. The distress in the Eurocurrency markets also contributed to the market stresses that led to the United Kingdom's 'fringe banking crisis' in 1975.

<sup>9</sup> For example, World Economic Forum (2010), p. 5, “The biggest risks facing the world today may be from slow failures or creeping risk...These are risks linked to big shifts that are recognized .... For example, global population growth, ageing and the ensuing rise in consumption, have implications for resources, climate change, health and fiscal policy”.

will reach nearly \$28 trillion by 2050, equivalent to 18% of global GDP (UNEP FI & PRI, 2011, p.20). Meanwhile, estimates indicate that around \$1 trillion of additional investment is needed annually through to 2030, for new green infrastructure in energy, transport, buildings and industry (World Economic Forum, 2013).

Some believe that these externalities are controlled and even mitigated through adaptations in the economy, such as alternative production processes and re-directing transport routes to avoid flooded coastlines (Nordhaus, 2013). According to this view, investors, aware of the scientific evidence supporting the risks from climate change, would be expected to discount the value of high carbon assets and increase the value of low carbon assets, resulting in investment shifting over time to low carbon assets. Nevertheless, the history of financial crises demonstrates that financial markets suffer from serious over- and under-estimation of risks because of asymmetric information and moral hazard resulting in large externalities for the economy and society (Eichengreen, 1999, pp 80-82; Aliber and Kindleberger 2015). Moreover, financial stability is a public good and market participants do not have the incentive to invest the necessary capital to provide it themselves because the benefits of stability spill over to free-riders who do not have to pay for it.

These examples demonstrate historic linkages between risks arising both from the environment itself (e.g. extreme weather events) and from humanity's management of scarce environmental resources (e.g. soil quality and oil) and financial instability. History alone therefore raises the fundamental question of whether central banks should take into account the price and financial stability risks that can arise from environmentally unsustainable practices.

The risks from climate change are undoubtedly amongst the most important and urgent facing the world today – the annual 2019 World Economic Forum Global Risks Report was once again dominated by climate and environmental factors amongst the top ten risks.<sup>10</sup> But what is it that central banks can reasonably do to limit or mitigate the risks from climate change?

## 1.2 *Central Bank Responsibilities*

Central banks have developed into a relatively successful class of public institution, largely since the 1990s when many were given independent authority to pursue their monetary policy objectives by setting interest rates and the quantity of base money. This monetary policy model is now recognised as best practise globally across a wide range of developed and developing countries, even if it is less than 30 years since New Zealand led the way by adopting, in February 1990, the first explicit inflation target. By 2017, 40 central banks had an explicit Inflation Target framework and at least another 20 had a price stability objective operationalised in much the same way (IMF, 2018).

Monetary policy is not the only core responsibility of central banks. They include: the issuance of domestic currency in the form of bank notes; providing clearing and settlement accounts for the banking system; and responsibility for payments systems, especially for

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<sup>10</sup> Extreme weather events were regarded as the most likely of the main risks and the second most impactful after weapons of mass destruction (World Economic Forum, 2019).

Real-Time Gross Settlement Systems which settle across central bank accounts. All of these core responsibilities can be said to relate to the broad concept of 'sound money' or 'monetary stability' and its role in supporting economic welfare over the medium term.

Most central banks also have an actual or implied remit to preserve financial stability, either as a primary or secondary objective. This focus on financial stability has grown as a result of the GFC and can now be treated as core in most countries, although we note that the EU Treaty setting up the European Central Bank (ECB) is unclear about its financial stability role.

Some central banks also have responsibility for prudential regulation and supervision of the banking system and sometimes other financial institutions (e.g. insurers, pension funds). But in other countries (e.g. Japan, Sweden, Australia), prudential supervision rests with an independent supervisory agency or agencies. In this paper we try to address all central banks, regardless of national differences, and hence take the broadest view of central bank objectives.

Some central banks which are responsible for prudential supervision also have responsibility for other aspects of financial regulations such as conduct, market effectiveness, consumer protection etc. In large developed countries, these usually rest with a separate conduct or securities market regulator. In smaller countries (e.g. Ireland, Botswana), who are perhaps more resource constrained, all financial sector regulatory responsibilities are likely to be combined within the central bank. Since the GFC, the most noticeable changes have included the UK moving to a 'twin peaks' model, with separate prudential and conduct regulators; and the euro area creating the Single Supervisory Mechanism for bank regulation at the ECB.

These immensely powerful responsibilities are allocated to 'independent' central banks- which are unelected and largely technocratic organisations. Nevertheless, occasionally, central banks are put under pressure to take into account, or even take a leading role, on other highly political or social issues. Given all their existing responsibilities and pressures, on what basis could we expect central banks also to play a role in climate change policy? This is a question which is being increasingly raised, not just by campaigners, but by the central banks themselves (Schoenmaker, 2018; PRA, 2018a; Cœuré, 2018; Debelle, 2019).

### **3 Monetary Stability**

Monetary stability is perhaps the prime responsibility of a modern central bank. In developed countries it usually involves targeting price stability directly, although many countries (e.g. Hong Kong, Denmark) remain focussed on the exchange rate and a few countries still maintain targets for monetary growth (IMF, 2017).

The primary tools of monetary policy are market operations – involving the purchase and sale (or repo) of bank assets and government debt - to guide short-term market interest

rates and the supply of the narrow money base.<sup>11</sup> In principle, a central bank should not be able to set both the price and quantity of narrow money at the same time. But in practice, the demand for narrow money seems to be relatively inelastic, especially at low interest rates. In recent years, with interest rates close to zero, the focus in many larger countries (US, euro area, Japan, UK) has been on expanding the supply of money through Quantitative Easing (QE) to prevent deflation.

Central banks use these tools to seek a balance between aggregate demand and supply and to influence inflation expectations. The economic theory underlying central banks operating an independent monetary policy is founded on the effectiveness of policy over the medium term: in brief, that although there can be an observed short-term positive relationship between inflation and output, that relationship does not exist in the medium-term, and will disappear quickly if it is consistently exploited by the authorities, leading to ever higher inflation. The short-term trade-off generates a time inconsistency problem which will always tempt politicians to over-stimulate the economy for political gain in the short-run, whereas committing to keep inflation low and stable is now generally agreed to be a prerequisite for maintaining sustainable growth and hence is in the broader public interest.<sup>12</sup> Similar medium-term considerations apply to both financial stability and micro-prudential supervision: seeking to steer a medium-term, resilient path for the economy rather than maximising (or allowing financial firms to maximise) short-run profits which could lead to subsequent, costly crashes.

In the context of climate change, the imperative is to take a longer term view<sup>13</sup> of sustainability than just the 5-7 years of the business cycle or the somewhat longer credit cycle. Sustainability needs to be considered across generations if the right policy choices are to be made concerning these risks. This was set out clearly in the Stern Review (2006) and then in the seminal speech on the topic by Mark Carney at a time when he was both Governor of the Bank of England and Chair of the G20's Financial Stability Board (Carney, 2015).<sup>14</sup> Carney described it as the 'Tragedy of the Horizons' in which the costs of preventing or mitigating the effects of climate change are lower, the sooner action is taken. But since the benefits largely accrue to later generations, current generations may not be willing to bear the costs. The likely consequence is much more costly actions, taken later.

In economic terms, this can be couched as suggesting that current decision makers should employ a lower discount factor than previously, in relation to future welfare. We might also regard this as a market failure – that there are negative externalities to current decisions, which are not currently being priced properly. For many economists, the first-best solution is to apply carbon taxes to correct the externalities directly – but for various reasons, including lack of international co-ordination, that route does not seem to be making progress. Carbon taxes are clearly a government responsibility rather than for the central bank.

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<sup>11</sup> The narrow money supply, or base money, we simply define as bank notes in circulation plus private sector deposits held at the central bank in domestic currency.

<sup>12</sup> This is described in the Annual Remit given to the UK's Monetary Policy Committee, see H M Treasury (2018).

<sup>13</sup> See for example EC (2018a).

<sup>14</sup> There are other notable contributions, including, for example, Garnaut (2008).

The financial risks associated with climate change, however, are relevant to central banks because of the potential impact on monetary policy and in particular on price stability. In considering this, we can analyse the potential impacts of climate change through the now standard classification of Physical and Transition risks (e.g. PRA, 2015). As global temperatures rise, and so do sea levels, the impact of physical climate events such as droughts, storms, floods and wild fires, could cause large relative price shocks: especially for food and other agricultural-related produce. There will also be price shocks arising from the transition to a lower carbon economy or to a higher temperature economy (possibly both) caused by changes in economic structure affecting the demand and supply of goods and services e.g. demand for energy efficient transport will likely rise, as might the demand for air conditioning systems. Longer-term impacts could include the re-location of large populations from flooded or drought-stricken sites.

Some of those transitional changes will be driven by policy interventions – in favour of electric cars rather than petrol and diesel for example. Policy interventions can also vary the rate of change and the relative costs of options – for example through infrastructure investment and economies of scale. Following Stern and Carney, we can say that both the physical and the transition effects will be later and more adverse if policies to limit climate change are not taken early or initially prove ineffective.

These economic changes represent supply-side shocks, and the likely impact on inflation will be at varying frequencies: relatively slow moving changes in price differentials in response to demand and supply trends, and sudden volatility in relation to supply shocks. In both cases, the change in relative costs may cause a rise in the retail price level and show as a temporary upwards movement in recorded inflation – possibly for some years - but not as a permanent change in inflation unless inflation expectations also rise and policy is accommodative. In the past, such effects have been evident in the case of oil price shocks and, to a lesser extent, food prices.

Monetary policy is simplest to set when dealing with aggregate demand shocks – if output and (expected) inflation rise together, then the obvious policy is to tighten (and vice versa for negative shocks). But supply shocks drive inflation and output in opposite directions and policy is then less clear. For example, tightening to bring down inflation after a supply shock could worsen the fall in output – a high cost if the inflation movement is likely to be temporary. To illustrate, suppose that there is a sudden step change in energy prices (e.g. from an economy-wide tax change). That would cause an increase in annual inflation for a year and could give an inflationary kick to other prices and wages that would last longer. In such a scenario, tightening monetary policy could be perverse – by the time the tightening had effect, most of the inflationary increase would have passed through and short-term output losses would have been increased by the policy action. So policy should be tightened only if there is a significant risk of inflation expectations becoming de-anchored, threatening a more general inflationary outcome.

The appropriate monetary policy response to a particular price shock could be confined to communications aimed at anchoring expectations, rather than a change in interest rates or money supply. But we can imagine that the more frequent that such price shocks occur, the

more likely it is that policy would actually need to be tightened in order to keep inflation expectations anchored.

### *3.1 What can monetary policy do to mitigate the threats from climate change?*

There are perhaps three main considerations. Firstly, we observe from the GFC, and previous crisis episodes, that when monetary or financial stability is lost, the resources of governments and central banks alike become devoted to short-term crisis management. Losing short-term control of the economy is probably the easiest way to lose sight and control of any longer-term agenda. Indeed, one of the main motivations for low and stable inflation is precisely that it enables economic agents to concentrate on matters related to real outcomes and long-term planning without being distracted by the costs of inflation or short-term boom and bust. So the first conclusion is that central banks must not compromise on their core objective of monetary stability. Sound monetary and financial control is a pre-requisite for a long-term sustainable economy.

Secondly, central banks may need to adapt their analysis. Most of the time, monetary policy is set by moving interest rates or the money supply – or the rhetoric around both - to edge aggregate demand in the economy towards the sustainable growth rate and hence remove any impetus to inflation moving away from its target. As noted, supply shocks make that more challenging. Also, given that the full effects of climate change have not yet been realised, the sustainable growth rate itself may be slightly different than previously. Most likely a bit lower, although this is by no means certain: investing in new, energy efficient technologies, and the displacement of old inefficient infrastructure, could be a stimulus to measured and sustainable growth rates.

The likely change in supply-side trends, and the increased prevalence of shocks, means that central banks may need to refocus their analytical abilities even more on the supply-side, rather than on aggregate demand. In the past thirty years of inflation targeting, it was widely thought that changes in potential growth were too slow moving to be very relevant for monetary policy, and routine analysis was therefore focussed on aggregate demand. To the extent that the supply side was important, it was labour markets that were most of interest, as that had been a source of inflationary expectations manifesting themselves via wage increases.

Estimates of non-inflationary (i.e. sustainable) growth – in terms of its level and rate of change – have actually never been very precisely determined, with estimates tending to vary pro-cyclically. But in many developed countries, productivity growth has slowed markedly since the GFC. More focus on measuring the long-term potential growth rate – and explaining that to business and the public - is probably warranted. It is quite likely that improved supply-side analysis would also require changes (improvements) to official statistics on certain aspects of the economy.

Thirdly, central banks have monetary tools that involve adjusting the size of their own balance sheets to change the level of base money supply. These tools could affect the supply of credit or liquidity for banks and the financial system to support lending and investment in environmentally sustainable sectors of the economy. As discussed above, modern central bank monetary policy involves targeting of consumer price inflation and using an array of

measures to ensure that the target is achieved. The economic slowdown in Europe, the US and Japan in the aftermath of the GFC has led the world's most influential central banks – the US Federal Reserve, the European Central Bank, the Japanese Central Bank, and the Bank of England – to follow extraordinarily loose monetary policies involving the use of certain measures that affect the supply of credit in the financial system; for instance, through the use of quantitative easing and generous terms for long-term funding for banks to encourage them to lend more to the broader economy.

Between 2009 and 2014, the Bank of England followed a 'Funding for Lending' scheme that involved the central bank providing liquidity at low interest rates to banks, secured largely on illiquid assets, in order to reduce the pressure on bank funding that had been driving up interest rates paid on deposits. The amount of liquidity was linked to the extent of increases in lending, and when the scheme was extended after the initial period, banks that used the scheme were obliged to publicly report the amount of lending they were doing.<sup>15</sup>

The FLS, and similar schemes in the UK and in the Euro Area, raise the question of whether central banks should routinely make funding available to banks in order to promote increased lending to environmentally sustainable economic activity. Other central bank actions could involve, for example, buying green assets outright or accepting them as collateral in liquidity operations (although it seems unlikely that banks would hold many such assets in their treasury portfolios, given their long-dated nature and the high demand from customers).<sup>16</sup>

The People's Bank of China (PBOC) has already embarked on using central bank policy tools to promote more lending to sustainable economic projects (see People's Bank of China, 2015). The PBOC initiative involves utilising more proactive measures to provide additional liquidity support to Chinese banks, such as the acceptance of "green asset backed securities" as collateral for liquidity support for Chinese banks (Huan Peng et al., 2018). This involvement of the central bank in assessing the value of asset-backed securities as a green asset class suggests that central banks can utilise existing policy measures based on their traditional monetary and financial policy remits to steer bank lending and investment to more sustainable sectors of the economy. This could potentially lead to much greater bank lending for environmentally sustainable economic activities and provide more sustainable sources of funding for such initiatives.

In addition, the growing sophistication of China's wholesale securities and debt markets creates the potential for increased investment in green assets by institutional investors along with the creation of a secondary market for trading these securities. All of which would bode well for increased investment into Chinese green credit.

The consideration of these tools would involve central banks reviewing how their monetary operations are conducted, including for example, what assets they hold to back the money supply. However, those choices cut across monetary and financial stability and so we come

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<sup>15</sup> See Fisher (2013) for an assessment of the FLS.

<sup>16</sup> In principle, green assets are already acceptable collateral where other corporate bonds are accepted e.g. ECB and Bank of England Level B and C collateral sets. But this is not widely appreciated.

back to balance sheets as a separate topic, where we also consider quantitative easing. First we focus on one particular balance sheet-related aspect, which is the note issue.

### 3.2 *Bank Notes*

An area of monetary policy that is directly relevant to carbon emissions is the issuance of bank notes. Although the actual process of printing banking notes is largely industrial and often outsourced, central banks retain the policy responsibility and in some cases they operate the actual printing presses. An important policy choice for central banks concerns what substances the bank notes are made from.

Traditionally, banknotes were made from a cotton-based paper. But polymer bank notes have been in circulation in some countries for decades (Australia since 1988) and introduced in others more recently (Canada in 2011; UK in 2016). To meet government commitments to limit global warming, it should be expected that all manufacturing processes will come under pressure to be more energy efficient and less polluting. So how does the choice of polymer versus more traditional paper stand up to analysis?

Polymer bank notes are more durable than paper-based notes and, perhaps surprisingly, easier to recycle, but they cost more to produce. A conservative estimate by the Bank of England when introducing polymer notes for the UK was that they would last 2.5 times longer than a paper-based equivalent. Based on that estimate, a Life-Cycle Analysis commissioned from an independent consultant concluded that polymer had less environmental impact than paper, on all 6 of the impact scores considered (Bank of England, 2013). More recently a report commissioned from The Carbon Trust by the Bank of England (Bank of England, 2017) has certified that over their full life cycle, the carbon footprint of a £5 polymer banknote is 16% lower than the previous £5 paper banknote, while the carbon footprint of a £10 polymer banknote is 8% lower than the £10 paper banknote.<sup>17</sup>

Polymer notes also have security advantages. But at the time of launching a new euro10 note in January 2014, the ECB was reported<sup>18</sup> to have said that it had decided to remain with cotton notes, citing cost grounds (implicitly, over the improved security which might have suggested a change). There were no cost estimates disclosed and there is no documentation available on the ECB website concerning this decision.

Polymer notes cost more to print but this should be more than offset by the longer usage. Given the Bank of England studies, it is difficult for an observer to understand why the ECB persists with paper. It is possible that the initial capital cost was simply too high to make the change: if so this would be a classic example of the dilemma facing much potentially green investment, especially by the public sector. Any new piece of infrastructure tends to be greener and cleaner than what it replaces, and it can often produce a better product at cheaper cost over its lifetime. The problem is to fund the initial investment charge up front when government debt and deficits are already thought to be excessive.

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<sup>17</sup> All documents available from Bank of England website:  
<https://www.bankofengland.co.uk/banknotes/polymer-banknotes>

<sup>18</sup> See Reuters (2014).

For banknotes, the lifetime cost comparisons should be favourable to polymer, but public investment can be constrained by other binding economic factors such as the existing fiscal deficit and/or stock of debt. There may also be political issues in the euro area: banknotes are printed across various euro area countries and it is possible that the reduced quantities needed for more durable polymer notes, or the technical difficulties of producing them, could have threatened the viability of production by a number of smaller member states. But without any ECB analysis published, this must remain a conjecture.

### 3.3 *Policy recommendations in relation to Monetary Stability*

It is recommended that central banks should keep a focus on low and stable inflation as a priority, to support the sustainable growth rate, but take a long-term (inter-generational) view of what growth model is sustainable. In considering the impact on price stability of climate change risks, they should continue to shift the balance of their economic analysis to the supply-side and potential growth, relative to short-term demand fluctuations.

National authorities should consider their role in developing targeted **monetary policy** measures that would assist banks in providing more funding for green lending. For instance, central banks could consider whether to accept certain high quality green assets as collateral for central bank loans to banks. It would be useful as a first step to clarify the extent to which any green assets were already eligible.

Central banks should also help set market-wide standards<sup>19</sup> that allow banks and other financial institutions to use simple and transparent financial instruments and investment structures to facilitate longer-term investment in green assets and other forms of environmentally sustainable economic activity. For instance, green asset-backed securities issued in transparent and simple structures could increase long-term investment in green credit and related assets.

Finally, all countries should consider moving to polymer banknotes, and, if no change is made, the reasoning should be published in full.

## 4 **Central Bank Balance Sheets and Quantitative Easing**

Central bank balance sheets are primarily used to implement monetary policy. Whether there is an exchange rate target or an inflation target, the policy instruments of interest rates and/or the narrow money supply must be adjusted to suit. Foreign Exchange Reserves may also be part of the central bank balance sheet, and used for monetary policy purposes, but this varies between jurisdictions. Occasionally, central bank balance sheets are used to support financial stability, in part by being Lender of Last Resort (LoLR) to the banking system.

The central banks of most of the world's large developed economies began quantitative easing (QE) during the GFC, undertaken as a combination of both their monetary and financial stability responsibilities. After interest rates were cut to near zero, QE involved

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<sup>19</sup> One way to do this is through collateral eligibility rules.

buying large quantities of financial assets. That automatically injected historically large amounts of base money and hence liquidity into the system.

One of the main motivations for QE was to counter the risk of deflation – falling prices - at the same time as stagnation in output, which could have been very difficult to escape had it come to pass. The success of QE was in pushing inflation back up towards a positive target when it would otherwise have been heavily negative. In essence QE was deliberately inflationary. Arguably it was most effective during the periods in which financial markets were dysfunctional – during 2008-09 and then 2012 during the euro area and Greek sovereign debt crisis. At this point the liquidity properties of the narrow money supply were heightened in importance relative to other assets.

Fisher and Hughes Hallett (2018) suggest that it is likely that central bank balance sheets will remain much larger than before the GFC, since banks now require many more liquid assets to meet their new Basel minimum liquidity requirements. The money injected into the system by central banks, through asset purchases, by necessity ends up either as more bank notes or, much more likely, as commercial bank deposits with the central bank. Those deposits are the most liquid asset a commercial bank can hold and are used to make inter-bank payments.

Expanded central bank balance sheets have highlighted several questions including how large they could be and what assets should be held? In particular some politicians and campaigners have argued that central banks could invest in social or green assets (“People’s QE” or “Green QE”). The problem has become acutely political for the ECB which bought large quantities of corporate bonds, and some Members of the European Parliament are demanding to know what the carbon footprint of these assets is, and why climate change risks are not taken into account when selecting bonds for purchase.<sup>20</sup>

We first note that QE operations take some assets out of the market to be held by the central bank and inject cash in their place. Most investors do not want to hold cash given its very low rate of return (often zero) and so their demand for all other financial assets goes up. This ‘Portfolio Balance Effect’ is one of the chief channels through which QE is effective – the behavioural response raises asset values, reduces spreads and brings down long-term interest rates, as investors search for higher yield. So any QE programme will have supported green assets along with all other assets.

The choice of assets purchased can also matter: to the extent that they include government debt, there is a one-off benefit to government funding. Depending on rules against monetary financing, government could use that benefit to fund green investments if it chose.

More generally, where demand for particular private sector assets has been especially weak, and/or spreads wider than objective risk would imply, central bank purchases of those assets can reduce such distortions by taking a portion of them out of the market. This can be termed ‘Credit easing’. Should this be used to justify the purchase of green bonds?

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<sup>20</sup> See the European Parliament Committee hearing transcript from July 9 2018 at ECB (2018).

As it stands, there is no shortage of demand for green assets – if anything there is insufficient supply. The evidence for that comes in the fact that green bond issues are regularly increased in size during the issuance process, without any detrimental effect on price.<sup>21</sup>

Given this analysis, there is currently no green policy case for central banks buying assets such as green bonds. It would simply crowd out private sector purchases by removing those bonds from the tradeable market at a time when the investor base is still growing rapidly. That is more likely to disrupt market growth, rather than add to it. Meanwhile, existing QE will have been indirectly supporting private sector demand for all assets. The balance of demand and supply may change in future but for now the purchase of green assets by the central bank would likely be counter-productive.

There are also a range of more practical arguments. Central bank balance sheets need to be able to both expand and contract quickly – whatever assets are purchased for monetary purposes need to be assets which can be sold quickly if policy requires it. Central banks are not natural long-term investors in private sector assets in domestic currency. And if central banks were to buy assets on ESG grounds they would need to be able to identify them – that would currently be difficult given the lack of market standards, even if central banks had the relevant skills.

Overall, there are good practical and mandate reasons why central banks might prefer neutrality in their asset purchases. But a counter case can be made. Suppose central bank balance sheets stay enlarged, because of commercial bank liquidity requirements, or for other reasons. Then there will be a large portion of their asset base which is not likely to be adjusted in future for any other policy purpose, nor is there otherwise a clear policy reason for holding any particular type of asset. Some portion of the expanded balance sheet could be allocated to hold long-term assets other than government bonds, perhaps in an investment tranche.

There could also be innovative arrangements for central banks to manage an investment tranche – for example in an off-balance sheet Special Purpose Vehicle (which the Bank of England used to hold its QE purchases). Such a mechanism could be used to address issues of mandate, governance, skills and risk.

Finally, there is one other area where central banks could amend their balance sheet operations: transparency. The recommendations of the FSB Task Force on Climate Related Disclosures (TCFD, 2017) were not designed for central banks, but they could be adapted.

The ECB is under particular pressure to release details of the carbon footprint of the assets it has bought. That would require the footprint to be calculated first, which is not straightforward. But the reporting problem might be solved another way. Since the portfolio is not being held for active trading purposes, the ECB could be much more transparent

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<sup>21</sup> There is mixed evidence on a price gain for the issuer – but this might be because the demand is met with a quantity response rather than a price response.

about what assets it holds for monetary policy purposes and then any observer could make their own calculations about how green those assets were. The market has always known what assets the Bank of England bought for example, whereas the purchases and holdings of the ECB are more obscure.

Rather than attempting to buy green assets, the best policy action by the authorities currently would be to help improve issuance of green securities. Singapore has already done this by subsidising the cost of green bond issuance. And the European Commission is working on a Green Taxonomy that could underpin an EU Green Bond standard. Central banks could also use their convening powers to help in the development of market standards, where necessary. To the extent that central banks should buy green assets, that might be more helpfully considered as part of an investment tranche, rather than as part of their QE portfolio. That way the investments themselves could be sustained rather than be subject to the needs of monetary policy.

#### *4.1 Foreign Exchange Reserves and Sovereign Wealth Management*

Central banks often hold large quantities of foreign exchange reserves on balance sheet, or manage them on behalf of government. We can divide reserves into broadly two purposes. Those currency reserves held for transactions such as potential intervention in foreign exchange markets, and those reserves which are held for investment purposes. Where the latter portion is large, it is often split into a Sovereign Wealth Fund (SWF). Governance varies from the central bank owning the SWF (e.g. Botswana) to managing it (Norway), to having partial responsibility (China) to having none (e.g. Singapore). Leaving aside the policy tranche, the investment funds/SWF can be very large and very significant international investors – China has \$3trn of reserves and the largest single SWF is the Norwegian Government Pension Fund Global at over \$1trn.

The considerations for managing such funds are very similar to large private sector asset managers except for the fact that there may have more political/social mandates, and they might be expected to take rather more externalities into account. But the simple point is that these funds are for national saving and should be used to generate sustainable returns for future generations. We should therefore expect SWFs to demonstrate best practice in managing their investments sustainably. For example, that may mean avoiding the obvious downside tail risks from investing in the coal industry. Decisions by the larger SWFs, such as Norway's, could be more important for their leadership signal than anything the central bank might otherwise do with its domestic balance sheet.

#### *4.2 Policy recommendations for central bank balance sheets*

In line with their mandates, and in particular their secondary objectives, central banks should be prepared to engage constructively with their governments around the use of expanded balance sheets to explore and explain in what ways they can, or cannot, be used to support wider government social and economic objectives.

Central bank purchases of large quantities of green assets, under current market conditions, could disrupt market development by crowding out private sector investors and thus be counter-productive. So QE portfolios – which also need to be reversible - are not appropriate vehicles. But an investment tranche might be appropriate for a balance sheet

which is expected to stay expanded. Some consideration should be given to whether a portion of the assets held on, or off balance sheet, could be sensibly invested in social or green assets, and what governance and staffing would be needed to oversee them.

The central bank should either (a) be completely transparent about all its holdings of assets for monetary policy purposes; and/or (b) it should regularly commission an independent calculation to establish their portfolio's carbon footprint. It should also encourage disclosures by market participants, in line with TCFD recommendations.

If and when lending re-emerges as the marginal policy tool for adjusting the size of the narrow money supply, central banks should clarify and publicise the eligibility of green assets and consider the 'brown' risks in their collateral by applying similar risk management frameworks that supervisors demand of commercial institutions.

## **5 Financial Stability**

Financial stability is harder to assess than monetary stability, as it pertains to the continuity of provision of financial services, which is challenging to measure outside of a crisis. But one certainly knows when it has been lost, as it was in 2007-09. Such systemic crises usually occur when risks have accumulated unseen or been under-estimated and then suddenly crystallise. Ideally, one would aim to prevent severe financial shocks from happening. But, recognising that it is inevitable that unforeseen shocks will occur, financial stability policy is oriented towards making the financial system resilient. Hence an objective that some regulators would like to set for the banking system (and other authorised firms) is to hold enough capital to absorb severe but plausible losses under a stress scenario, whilst continuing to provide financial services to their clients, and for the inter-connections between institutions not to be such that a single failure brings down the system. Co-ordinated stress tests are now undertaken to help meet this objective, in the US, the euro area and the UK.

The main financial stability risk from climate change is that there could be a sufficiently large and widespread fall in financial asset prices, perhaps from stranded assets for example, to cause system-wide effects that disrupt financial services.

Financial market prices do not always adjust smoothly. They are forward-looking, which means that particular pieces of news are extrapolated to take account now of future implications (or to look for similarities now, across sectors). This can cause asset re-pricing to be exacerbated, potentially to large jumps. Not just re-pricing single securities, but whole asset classes. A key point here is that market prices reflect perceptions about the (discounted) future which can be very uncertain – and uncertainty itself will also affect prices as an additional risk premium, on top of any central estimate.

Climate news events that could cause large market price jumps might include changes in public policy concerning fossil fuels, or perhaps electric vehicles rapidly displacing petrol/diesel powered vehicles. Such shocks would affect at least 2 large sectors in many stock market indices: energy and automotive (the latter including not just vehicle

manufacture, but garages, servicing, parking, taxi cabs etc.). Changes in energy policy have already led in whole, or in part to significant changes in the prices of individual stocks (RWE and Eon in Germany; Peabody Energy in the US).

One can imagine financial market dislocations arising from physical events, should they be sufficiently severe or simultaneous. An extreme example would be if there were floods in London, severe hurricanes in New York and an earthquake in Tokyo by random chance at the same time. Not only would markets be disrupted by those events, but also by changing assessments of the likelihood of future disruptions.

Market price jumps could also occur as a result of transition risks crystallising, via sudden government policy changes – especially if global in impact. These would be regarded as extreme tail risks, but preserving financial stability requires being robust to tail events.

One policy response to the risks of climate change, which would make the system more resilient, is to have more public information on climate related exposures of corporate entities. Such information can be used to price the risks that firms face (including the credit risk in loans), and to re-price should an event change perceptions of the future. That should mean that jumps in asset prices occur less frequently and that re-pricing is more accurate, which should lead to smaller jumps.

A side benefit of disclosure is that the firm disclosing must first evaluate the risks that it is exposed to and, where that is bad news to it, or to the market, that alone may prompt changes in behaviour. The risk of an immediate negative price reaction for the individual firm is a disincentive to disclosure and so the worst carbon emitters are likely to be the least likely to disclose voluntarily. That would argue for making such disclosures a legal requirement.

The main policy initiative on this front has been the work of the G20 Financial Stability Board and the Task Force (TCFD) it set up to make recommendations on voluntary Climate-Related Financial Disclosures. This was a private-sector led Task Force, chaired by Michael Bloomberg, whose report in July 2017 (TCFD, 2017) concluded that the firms should report, in their main financial filings, what they are doing about managing climate related risks in four areas: Governance, Strategy, Risk Management and Targets and Metrics. Specific advice was given for certain industrial and financial sectors although the Report is not a blueprint for disclosures. In particular it argues for scenario analysis to assess the risks facing a company, particularly for the transition to a lower carbon economy.

A number of countries have endorsed the TCFD recommendations, including the EU and the UK, and hundreds of large companies around the world are seeking to implement (see update TCFD, 2018). In the longer-term, once the methods for disclosure have become settled, it is probably inevitable that such disclosures will be written into reporting requirements – the EU is already moving in that direction with changes to the Non-Financial Reporting Directive (EC, 2018b). Financial stability authorities, including central banks, can help make sure that full disclosure takes place in the financial sector.

Finally, we note that changes in technology could cause significant disruption to the financial system. Examples might include peer-to-peer lending, digital currencies or new payment systems. Such changes should be beneficial if they meet the needs of the economy with cheaper and/or more efficient financial services and the authorities should not seek to protect existing franchises from the consequences of structural change. But the financial stability authorities will need to keep a close eye on the risks, including that existing institutions might fail, resulting in discontinuities. Some of the technology risks are also for the relevant conduct authorities to consider, including electronic scams; increasing damage from cyber attacks; data misuse; and easier routes to money laundering and criminal/terrorist funding.

On the positive side, new technology is likely to be necessary to generate the transition to a low carbon economy. Carbon (dioxide) capture, use and storage will almost certainly be required to reduce the level of carbon dioxide in the atmosphere. And there is also 'green fintech' – using distributed ledgers and other technology to help improve sustainable finance. Examples are given in CISL (2017) with at least one proposal being developed for commercial launch – to help track soft commodities sources to reward sustainable producers.

One observation from climate change work in practice is that few companies have the resources and knowledge to manage this issue alone. New coalitions are being created to share best practice. The CISL (2017) proposals were produced by a coalition of banks working as the 'Banking Environment Initiative' under the auspices of the Cambridge Institute for Sustainability Leadership (CISL). Central banks can play a similar role in facilitating discussions between commercial enterprises, without deleterious effects on competition and they now have their own Network for Greening the Financial System (NGFS).

### *5.1 Policy recommendations for financial stability*

In considering policy recommendations, it should be recognised that financial stability is not just a matter for central banks, and so some recommended policy actions must be exercised in conjunction with or through other regulatory authorities. National authorities should implement TCFD recommendations through domestic regulatory requirements. Banks and other market participants should be sufficiently aware of the risks and their systemic nature, and that they should identify and prepare for physical events that could cause financial instability e.g. disasters in major financial centres and make contingency arrangements accordingly. The relevant authorities should look for opportunities to provide 'safe spaces' for new developments by private actors in financial markets to address common problems. Finally, supervisory authorities should use their powers to address risk management in authorised firms.

## **6 Prudential Supervision**

Not all central banks undertake prudential regulation and supervision, but even where not, they are usually a key stakeholder and policy contributor through their interest in financial stability. Broadly speaking we can describe regulation as setting and enforcing rules, and

supervision being a more investigative and intrusive over-sight. Both have a role to play. In this section, we first outline the nature of the risks in insurance and banking and then consider how regulators might intervene. Similar analysis could be extended to cover other authorised institutions.

### *6.1 Insurance Supervision*

In 2015, the Bank of England's Prudential Regulation Authority published an influential paper on the risks to the UK insurance industry (PRA, 2015). This has been followed with an assessment of risks to the UK banking sector (PRA, 2018a). Insurance firms are in the front line for climate risks, as it affects both their under-writing and asset management functions. The market has broadly three categories of insurer, each facing different risks: general, life and re-insurance.

- i) General Insurers are those who write insurance policies for retail and corporates relating to day-to-day risks such as accidental damage, loss, theft etc. These policies cover general business and consumer disruption, including climate-related events such as floods, storms and droughts and even catastrophes. Their modelling has to reflect the trends and the tail risks. These policies can usually be re-priced every year and so the general insurance industry – providing it stays alert and extrapolates reasonably - can protect itself. Indeed, it has a key part to play in climate risk adaption – helping to spread the costs from global warming over time, space and people.

In much of the world, especially in poorer countries, insurance coverage is weak. And particular risks may become uninsurable even in developed countries. For example, as sea levels rise or rainfall increases in certain areas, flood insurance may no longer be available. In the UK, this has led to the Government and Industry jointly creating Flood-Re – a reinsurance company that helps insurance companies to pass on their more extreme risks.

Climate losses can also be large and unpredictable. A report by Lloyd's of London (Lloyd's, 2014) into Super Storm Sandy in New York in 2012, estimated that the losses from the ground water upsurge were increased by some 30% (c\$6bn) because of the rise in sea-level at the Battery, of some 20cm since the 1950s.

- ii) Life insurance companies (or superannuation funds) face additional risks on the asset side. These insurers should match their longer-term liabilities with similarly long-term assets. Not only are the liabilities harder to value, the assets are also subject to physical and transition risks. Especially property which might otherwise be a good long-term asset for such portfolios.
- iii) The other main type of firm is reinsurance companies. Insurers can reduce capital requirements by having portfolios of diverse underwriting risks – if uncorrelated enough they shouldn't all crystallise at the same time, so capital can do 'double duty'. By passing some of their concentrated liabilities to a large reinsurer – or even their own related 'mixer' company – diversification can be increased and capital requirements reduced. There is a risk from climate change, however, that

correlations may change e.g. climate events could become more directly inter-dependent, in which case the diversification benefits for under-writing may be over-estimated, and the risk of loss on assets underestimated simultaneously – an example of ‘wrong-way’ risk.

All of these reasons mean that insurance supervisors and authorised firms alike have good reason to pay attention to climate change risks in their business and capital modelling.

## 6.2 *Banking*

The risks for banks are arguably more nuanced. Banks may think they have less to fear from climate change because their assets tend to be shorter-term, and they take security against loans. We will argue that both are mistaken arguments. Banks lend to some activities which are ultimately unsustainable – such as the coal industry. Over time, the associated credit risks will increase, and could crystallise suddenly: Peabody Energy, the world’s largest private coal producer eventually filed for Chapter 11 protection in the US, after a US Government shift in policy in favour of gas.

Short-term lending is not always less risky than long-term - the original maturity date of a loan is not relevant if default can happen suddenly. A portfolio of long-term loans and a similar-size portfolio of short-dated loans that is constantly replenished at maturity, could yield the same losses if default happens overnight – what matters is the business model of the bank and the speed of surprise.

A related example of this risk crystallised at the start of the GFC. Banks that operated an ‘originate to distribute’ model got caught out by the sudden closure of markets. Longer-term (typically mortgage) assets were originated with a view to being securitised. In that business model, loans were made and then ‘warehoused’ on balance sheet whilst being prepared for securitisation. That exposure would have been seen as a short-term position and funded accordingly. But the securitisation markets shut very suddenly and banks had to find sustained funding for those existing portfolios. In many cases they had to take existing securitisations back on balance sheet. In the case of Northern Rock, the closure of the market was a sufficient liquidity shock for the institution to fail. The relevant part of that experience is that, although banks were turning over such assets quite quickly, they were at risk if the markets closed overnight. Similar arguments apply to portfolios of traded securities held for market-making purposes. Indeed, during the GFC, many traders were caught holding portfolios of corporate bonds for market making at a time when their prices fell suddenly. It was the speed of the shock that really mattered, not the maturity of the asset. In the climate space, any policy or physical climate event that causes a sudden shock, could catch a firm out, even if its positions are short-maturity.

The availability of collateral to take as security can also be a false comfort. Whether lending for residential property or to corporates, banks like to take such security to mitigate the risk of loss – and usually will not lend if none is available (e.g. some service firms where there is only human capital can find it difficult to raise bank credit). But that security is often in the form of property (e.g. for a mortgage) or plant (for a firm). Physical climate events could cause the borrower to default and could also wipe out the physical asset. Hence it is another example of a ‘wrong-way’ risk. There would be a backstop if the collateral is covered by

insurance, which it should be, at least in countries where insurance markets are widely developed. But banks do not typically keep records of whether their borrowers regularly maintain the relevant insurance cover, or check whether extreme climate events are covered. Even if buildings insurance was a condition of a mortgage, after a year the bank is in the dark if it does not check. Typically, banks do not know how much security they would really have in the event of extreme climate events.

Another risk for banks – and many asset managers – lies with sovereign risk. Some countries are specialist commodity producers including oil, coal, foodstuffs, metals and so on. Climate change could cause serious sovereign risks if those concentrated dependencies are affected. Oil producers such as the Gulf States will need to look elsewhere to generate national income, and are already seeking new models of economic development. Climate change could also affect those economies dependent on single agricultural crops – such as Ghana’s dependence on cocoa. If climate conditions changed sufficiently then such crops may no longer be viable. This will introduce credit risks not only in the private sector but also for the relevant government debt.

### 6.3 *The role of regulators*

The role of financial regulators, including central banks, is to make sure that the financial system remains stable. Their mandate is not to protect the shareholders of individual companies. Even if a financial firm needs to be publicly supported so it can continue to provide necessary services, the shareholders should be wiped out and senior management fired.<sup>22</sup> But the risks we are addressing in this paper are systemic and will most likely affect the whole financial system at the same time. We will focus on banks first.

Alexander (2014) argues that the Basel system of capital requirements has all the elements that are necessary to protect the system in the context of climate change. Basel regulations comprise 3 pillars. Pillar I is a system of minimum capital charges that apply to all firms, although there can be different approaches for some assets, depending on the sophistication of internal risk modelling. Pillar II is additional capital that is required to cover risks not captured by Pillar I. These will be idiosyncratic to the firm and its business model and can be imposed using supervisory judgement. Pillar III is market discipline through disclosure. All three pillars are potentially available to help with the risks from climate change.

Climate change represents a material financial risk. Regardless of the minimum calculations specified, the rules require banks to hold capital against all material risks that the firm has identified. Risks not captured in Pillar I, if material, can be included under Pillar II and reflected in capital ‘add-ons’ that are specific to the firm. These additional capital requirements could be used for a variety of reasons, including governance or risk management failings or business model risks. If the capital add-ons are in an area where remediation is possible, such as poor risk management, then they are usually intended to be temporary. Other supervisory interventions may also be used, as well as or instead of, capital requirements.

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<sup>22</sup> Different jurisdictions will have different approaches, some graduated, some proportionate to the size of the firm. On the other hand, some countries do not yet have any special resolution or recovery regimes for financial firms.

One obvious way forward is for supervisors to examine their firms to see whether climate related risks are being properly identified and risk-managed and capital is being held appropriately. If that is not the case, then capital add-ons can be either threatened or imposed to incentivise action. In itself, that pressure should help banks to decrease their exposure through lending to unsustainable activities.

This process is hindered somewhat by the lack of definitions of what assets are, or are not, sustainable. The EU is developing a taxonomy of green assets to remedy that, as part of its action plan on sustainable finance (EC, 2018b). But, at the current time, supervisory action needs to be justified on broad grounds of risk management, rather than related to specific assets.

There have been propositions in favour of reducing Pillar 1 risk weights to incentivise green lending. In particular the so-called Green Supporting Factor (EBF, 2018) which was proposed by some European banks to be an ad hoc cut of 25% in risk weights for 'green' lending. Alexander and Fisher (2019) argue that this would be a mistake on a number of grounds and is unnecessary.

We must recognise that, like monetary stability, financial stability is a pre-requisite for a sustainable economy and to ensure that, the Basel capital weights system is risk-based. It would be a mistake to jeopardise financial stability, and hence sustainable growth, by making non-risk based adjustments to capital requirements.

Pillar 1 capital weights are simultaneously very approximate and complicated. There are not yet any green asset classes defined to which differential capital weights could apply and there is no evidence yet that the risk-based weights currently in the Basel system are inappropriate for green lending. It is much more likely that lending to unsustainable activities, as a new risk hitherto not appreciated, could justify increased weights for 'brown' lending (if the latter could be identified). Producing evidence to support changes in risk weights would be a lengthy and difficult process. In contrast, Pillar II is immediately available and can be used by supervisors now, to (threaten to) directly increase capital requirements where banks do not have adequate risk management. That is the path on which leading supervisors seem to be embarked (PRA, 2018b), although until there are more specific definitions, it will be up to the banks to both identify their risks, and take appropriate action.

These arguments were rehearsed by the European Commission's High Level Experts Group on Sustainable Finance (EC, 2018a). The Commission promised to investigate the issue further, with the condition that risk weights should remain risk-based.

Similar arguments apply to the insurance industry. One difference is that the use of internal models to assess risk and capital is more comprehensive for an insurer which needs to link its assets to its liabilities. In contrast a bank typically judges its capital needs solely by its assets. In both cases the internal models used should eventually capture any risk benefits of green lending and any costs from brown, but these risks are not in the data underlying the models as yet, since climate change is an ongoing process. Ideally one needs to use forward-

looking scenario analysis to judge the extent of the risks and this may well be easier to do in the approach of insurance modelling, where balance sheets are simulated tens of thousands of times, using different parametric assumptions. A key conclusion is that one cannot judge future climate risk solely based on historical data.

#### *6.4 Policy recommendations in relation to prudential regulation.*

Supervisors should ensure that authorised firms are trying their best to identify and manage the risks from climate change and not simply ignoring them as uncertain or long-dated. This is the duty of supervisors within existing mandates. Properly assessing the risks requires a forward assessment that cannot be based solely on historical data. Supervisors can help in constructing scenarios and new forms of risk analysis that will help the industry to judge its capital requirements in the face of future threats. All the Prudential Pillars of the Basel regime should be considered. That includes Pillar III: disclosure rules should incorporate the voluntary TCFD recommendations and see them implemented on a mandatory basis – at least once the reporting techniques and standards have settled down.

Pillar I is the most problematic option. The Basel Committee on Banking Supervision should investigate the issue to see if any changes are warranted and if so, how they might be implemented. Supervisory action under Pillar II must not wait for that to happen - it can and should be happening under existing responsibilities. Senior management and Boards within firms need to be aware of the issues and take them seriously as part of their 'fit and proper' responsibilities. A variety of measures can be taken by regulators to ensure that happens. In the UK, the PRA has proposed that responsibility for managing climate-related risks be a defined function under the Senior Managers Regime, so that one very senior manager has to take it as a personal responsibility on behalf of the firm. (PRA, 2018b).

## **7 Market regulators: conduct, consumer protection and market efficiency**

Given a free choice, most central banks would probably avoid taking responsibilities for market issues such as conduct, consumer protection and competition. Setting these regulations, and enforcing them, is very important but it requires different skill-sets from other central bank responsibilities, and can deliver short-term priorities which monopolise resources, diverting them away from longer-term issues such as prudential regulation and financial stability. But in many countries it does not make economic sense to maintain separate regulators, and the central bank therefore has responsibility for all. So we briefly consider how climate change may affect these market conduct duties. This is new territory. The UK's Financial Conduct Authority is one of the first<sup>23</sup> conduct regulators to take climate risks seriously, and it published its first paper on the topic in October 2018 (FCA, 2018). So here we just sketch out some of the issues.

One imperative is that the financial sector provides services which meet the needs of citizens effectively. There is a growing demand for investment in green assets, but not much

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<sup>23</sup> ASIC in Australia is also on the case. See

<https://asic.gov.au/regulatory-resources/corporate-governance/corporate-governance-articles/disclosing-climate-risk/>

opportunity for the retail investor, who has limited access to information or suitable products. Promoting the development of effective markets to ensure they meet consumer needs is within the broad remit of at least some 'conduct' regulators<sup>24</sup>.

A particular issue is that Independent Financial Advisors do not appear to be routinely asking their customers about their sustainability preferences and thus do not end up recommending funds dedicated to sustainable outcomes – despite many opinion surveys revealing a latent demand. This is not simply a question of whether customers are willing to trade off some returns for the comfort of investing sustainably. There is growing evidence that companies with high Environmental, Social and Governance (ESG) ratings actually produce higher returns over the medium term. Following a recommendation from the Commission's High-Level Experts Group on Sustainable Finance (EC, 2018a), the EU are adapting the MIFID (Markets in Financial Instruments Directive) rules to make it a requirement for investment advisors to ask their clients about their sustainability preferences (EC, 2018b). That could be followed in other jurisdictions.

Given the demand by investors, both retail and professional, there is also an incentive to advertise investment products as 'green' when they are not. This so-called 'green washing' is clearly a conduct issue. In addition, many working practices of asset managers have been challenged for not being aligned to sustainable capital. This may include excessive churn of securities, excessive focus on very short-term returns, and a misunderstanding of fiduciary duty.

Fiduciary duty is a requirement – which differs somewhat across legal jurisdictions - that board members of companies have to look after the interest of stakeholders and to act with honesty and due care and skill in the performance of their roles (prudence and loyalty in parts of continental Europe). This has been interpreted at times to mean maximising the short-term returns for shareholders. In fact, fiduciary duty relates to the interests of the corporate entity as a whole, not just its current shareholders and not just to monetary returns – the future franchise value matters, as does the interests of employees.

In the past, some directors may have used the argument that Fiduciary Duty means that boards cannot take into account social issues which are not in the financial interests of shareholders. Recent legal opinions have turned this argument around. For example, Hutley and Davies (2016) argues that because climate change represents a clear and material financial risk – evidence for which is much more apparent than was the case in earlier legal cases (e.g. asbestos, thalidomide) – that Fiduciary Duty requires boards to assess the risks and take them into account. Failure to do so will leave directors liable in the event of climate-related losses. It will be incumbent on market regulators to pursue these issues, and new ones as they arise, through both rules and possibly through standards.

Compared with other topics in this paper, the following policy recommendations for regulators are more tentative, although a number of them have been advised by the European Commission's HLEG and are being implemented (EC, 2018a; 2018b).

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<sup>24</sup> For example, it is for the UK FCA, but may not be everywhere. It should be.

### *7.1 Policy recommendations for conduct and market regulators*

All funds offered to retail investors should be required to report simple sustainability metrics, preferably relating to impact. Those funds specifically offering themselves as 'green' or 'low carbon' should be required to provide evidence consistent with that label. All financial sector firms, including asset managers and independent financial advisors should be able to demonstrate awareness of the issues and risks to financial investments arising from climate change. Finally, financial advisors should be required to ask clients about the preferences for investing sustainably.

## **8 Joining up Banking Regulation with Environmental Policy**

A major weakness with existing approaches of financial policy/regulation and environmental policy/regulation has been the apparent lack of coordination between central banks, regulators and environment ministries in developing, implementing and enforcing rules and standards to promote more environmentally sustainable behaviour. The problem of coordination and mutual recognition of standards goes all the way to the international level, involving the G20 and international environmental initiatives. Historically, there has been a failure at the highest level to join-up financial policy with environmental policy in respect of putting the global economy on a more stable and sustainable footing. For instance, many bank supervisors do not believe that they have a policy mandate from their Finance Ministries to require banks and financial institutions to manage or report their environmental sustainability risks.

The G20 has recently recognised the problem: in 2018 under the Argentinian Presidency, it concluded that it should encourage more coordination between international financial standard setting bodies to achieve international sustainability objectives, such as the United Nations 2030 Development Goals and the reduced carbon emission targets of the 2015 Paris Climate Change Treaty. Although there has been a general failure until recently to recognise the importance of linking international financial regulatory objectives and environmental policy objectives, some countries have made progress in establishing institutional and legal linkages between environmental regulation and financial regulation.

The efforts of China and Peru should be noted, as they adopted coordination mechanisms between environmental and finance ministries and the central bank and regulators to ensure the exchange of information and data, and mutual support in investigations and enforcement of environmental laws. In these countries, central banks and financial and environmental regulators are required to coordinate their regulatory practices and supervision where environmental regulatory compliance and financial regulatory compliance implicate one another. Other countries, such as Brazil, have embarked on similar coordination policies by ensuring that databases of infringements of environmental laws and regulations are made publicly available, including to banks.

Most advanced developed countries, however – including most members of the Basel Committee – have no or inadequate coordination between the central banks and the corresponding environmental and independent banking regulators to promote sustainable finance. Moreover, in most EU states and the United States, bank regulators and supervisors

have not recognised that they have an official mandate to take account of environmental sustainability risks when applying and implementing their own regulatory frameworks.

Many countries in the World Bank's Sustainable Banking Network have developed national approaches that could serve as a model for the G20 and other international bodies to recommend to all countries. This generally involves countries developing a strong dialogue between the Environmental Ministry and the Finance Ministry with respect to financial exposures to environmental sustainability risk issues. While individual country approaches may not be readily transferable, it is certainly necessary as a first step for Finance Ministries to ensure that bank regulators have a mandate to supervise the banking sector's exposure to environmental sustainability risks. This will ultimately enhance bank risk management in the areas of credit, market, liquidity and operational risk.

## 9 Conclusions

In the wake of the financial crisis of 2007-08, there have been extensive reforms to international banking and financial market regulation, including greater scrutiny of the operations of central banks. This has been accompanied by the United Nation's adoption of the Sustainable Development Goals and the UN Climate Change Treaty. It is therefore imperative that central banks should play a lead role in coordinating the use of policy tools and measures with other financial and environmental regulators to generate strong, sustainable and balanced global growth. The urgency for policy and regulatory intervention cannot be over-stated as global economic activity has breached the Earth's planetary boundaries – defined as thresholds that, if crossed, could generate unacceptable environmental change for humanity and pose irreparable harm to the global economy. Such 'environmental sustainability risks' may be amongst the biggest risks that the world faces today.

In this paper we have set out an analysis of why and how central banks can and should be involved in addressing the financial risks associated with environmentally unsustainable activity including how the economy and policymakers can manage the risks associated with climate change. Central banks should not avoid the challenge. Environmental sustainability risks, such as climate change, affect primary central bank objectives through monetary conditions, financial stability and the prudential requirements of authorised firms (and market conduct where applicable). This arises as a result of either physical climate shocks or transition<sup>25</sup> shocks and those risks will be present whether global warming is successfully controlled or not. The central bank is responsible for the industrial production of banknotes and needs to play its part in sustainability as a manufacturer/purchaser. So, to a large extent the involvement of central banks in climate change is required under existing mandates.

Financial stability considerations suggest that central banks should go further than this, to positively promote a transition to a sustainable and hence lower carbon economy, as part of their primary objectives.

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<sup>25</sup> The transition could be to a lower carbon economy or not – but there will be a transition to some new economic state regardless.

The full recognition of secondary objectives, to support the government's wider economic policies, can also play a role in facilitating new approaches. Secondary objectives can be invoked particularly in the rather delicate issue of balance sheet management and the potential to use monetary operations, without compromising monetary objectives. It could be possible, for a central bank to buy green assets, perhaps as an investment tranche of its assets. A case remains to be made as to why there is benefit in the central bank taking such actions rather than the government – the financial arrangements are essentially equivalent, with the difference being one of governance and perhaps perception.

Despite these challenging technical arguments, the main point of this paper is that central banks have a duty to act under existing mandates and should be getting on with that - as indeed, some are. The new central bank and regulator group – The Network for Greening the Financial System - has grown rapidly since it was founded towards the end of 2017<sup>26</sup>. It has already achieved a remarkable track record of involving industry and academia in debating what should be done in financial markets, from the perspective of the authorities and private firms, and will doubtless reflect further on the issues in this paper.

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<sup>26</sup> See NGFS website hosted by the Banque de France: <https://www.banque-france.fr/en/financial-stability/international-role/network-greening-financial-system>

## References:

Alexander, K (2014), '*Stability and Sustainability in Banking Reform: Are Environmental Risks Missing in Basel III?*', Cambridge/UNEP, October.

<https://www.cisl.cam.ac.uk/resources/sustainable-finance-publications/banking-regulation>  
[Accessed 11/2/19]

Alexander, K and Fisher, P G (2019), '*Banking Regulation and Sustainability*' in F-J Beekhoven van der Boezem, C Jansen and B Schuijling (eds) *Sustainability and Financial Markets*, pp7-32. Law of Business and Finance Volume 17, Wolters Kluwer Netherland B.V.

Aliber, R Z and Kindleberger, C P (2015), *Manias, Panics and Crashes*. Palgrave Macmillan, 7<sup>th</sup> edition.

Bank of England (2013), '*LCA of paper and polymer bank notes*' available, along with other relevant papers at: <https://www.bankofengland.co.uk/banknotes/polymer-banknotes>  
[Accessed 11/2/19]

Bank of England (2017), '*Carbon Footprint Assessment: Paper vs. Polymer £5 & £10 Bank Notes*' <https://www.bankofengland.co.uk/-/media/boe/files/banknotes/polymer/carbon-footprint-assessment.pdf?la=en&hash=A2077D4BEF302DF8F8488503DEA041876627ECBD>  
[Accessed 17/2/19]

Bryant, K, and Rickards, J (2016), '*The legal duties of pension fund trustees in relation to climate change*'. Opinion commissioned and published by Client Earth, London.  
<https://www.documents.clientearth.org/wp-content/uploads/library/2016-12-02-the-legal-duties-of-pension-fund-trustees-abridged-opinion-ext-en.pdf> [Accessed 15/2/19]

Carney, M (2015), '*Breaking the Tragedy of the horizon – climate change and financial stability*', speech to Lloyd's of London, September.  
<https://www.bankofengland.co.uk/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability> [Accessed 11/2/19]

CISL (2017), '*Catalysing Fintech for Sustainability: Lessons from multi-sector innovation*'. Cambridge Institute for Sustainability Leadership, October.  
<https://www.cisl.cam.ac.uk/resources/sustainable-finance-publications/catalysing-fintech-for-sustainability> [Accessed 15/2/19]

Cœuré, B (2018), '*Monetary policy and climate change*', speech at the Bundesbank-NGFS-CEP Conference on "Scaling up Green Finance: The Role of Central Banks", Berlin, 8-9 November 2018. Available at:  
<https://www.ecb.europa.eu/press/key/date/2018/html/ecb.sp181108.en.html>  
[Accessed 13/2/19]

DeBelle, G (2019), '*Climate Change and the Economy*', speech, March 12. Available at:  
<https://www.rba.gov.au/speeches/2019/pdf/sp-dg-2019-03-12.pdf> [Accessed 13/2/19]

Dikau, S and Volz U (2019), '*Central Bank Mandates, Sustainability Objectives and the Promotion of Green Finance*'. SOAS, Department of Economics, Working Paper 222, March. <https://www.soas.ac.uk/economics/research/workingpapers/file139494.pdf> [Accessed 8/4/19]

ECB (2018), Transcript of hearing: Committee on Economic and Monetary Affairs monetary dialogue with Mario Draghi, President of the European Central Bank. [https://www.ecb.europa.eu/pub/pdf/annex/ecb.sp180709\\_transcript.en.pdf?d0bd98150affdcbcd1ea9e80f128b90b](https://www.ecb.europa.eu/pub/pdf/annex/ecb.sp180709_transcript.en.pdf?d0bd98150affdcbcd1ea9e80f128b90b) [Accessed 17/2/19]

Eichengreen, B (1999), *Toward a New International Financial Architecture*, Institute for International Economics, Washington DC.

ESRB Advisory Scientific Committee (2016), '*Too late, too sudden: Transition to a low-carbon economy and systemic risk*', Frankfurt, February. [https://www.esrb.europa.eu/pub/pdf/asc/Reports\\_ASC\\_6\\_1602.pdf?ea575bbcd2dd43eceb545ea146f9710](https://www.esrb.europa.eu/pub/pdf/asc/Reports_ASC_6_1602.pdf?ea575bbcd2dd43eceb545ea146f9710) [Accessed 11/2/19]

European Banking Federation (2018) '*Green Finance: Considering a Green Supporting Factor*', January. <https://www.ebf.eu/wp-content/uploads/2017/09/Geen-finance-complete.pdf> [Accessed 8/4/19]

European Commission (2018a), Final report of the High Level Experts Group on Sustainable Finance, '*Financing a Sustainable European Economy*', Brussels, January. [https://ec.europa.eu/info/publications/180131-sustainable-finance-report\\_en](https://ec.europa.eu/info/publications/180131-sustainable-finance-report_en) [Accessed 24/1/19]

European Commission (2018b), '*Action Plan: Financing Sustainable Growth*', March 2018. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0097&from=EN> [Accessed 24/1/19]

Financial Conduct Authority (2018), '*Climate Change and Green Finance*', Discussion Paper, October. <https://www.fca.org.uk/publications/discussion-papers/dp18-8-climate-change-and-green-finance> [Accessed 17/2/19]

Fisher, P G and Grout, P (2017), '*Competition and Prudential Regulation*', Bank of England Staff Working Paper no. 675, September. <https://www.bankofengland.co.uk/working-paper/2017/competition-and-prudential-regulation> [Accessed 15/2/19]

Fisher, P G (2013), '*Financial markets, monetary policy and credit supply*', speech given at Richmond University, London, October. <https://www.bankofengland.co.uk/-/media/boe/files/speech/2013/financial-markets-monetary-policy-and-credit-supply.pdf?la=en&hash=1AE9D84BD3CC1A8E0B3FCCDB13EDE6063CBA26C9> [Accessed 26/3/19]

Fisher, P G and Hughes Hallett, A J (2018), 'Can central bank balance sheets be used as a macroprudential tool?' King's Business School, DAFM Working Paper, 2018/6.  
<https://www.kcl.ac.uk/business/assets/pdf/dafm-working-papers/dafm-wp6.pdf>  
[Accessed 17/2/19]

G20 (2009), 'G20 Leaders Statement: The Pittsburgh Summit', September 24-25.  
<http://www.g20.utoronto.ca/2009/2009communique0925.html> [Accessed 31/3/19]

Garnaut, R (2008, 2011), 'The Garnaut Climate Change Review', Also see 2011 updates.  
<http://www.garnautreview.org.au/index.htm#pdf> [Accessed 13/2/19]

Goodhart, C A E (2011), *The Basel Committee on Banking Supervision: A History of the Early Years*. Cambridge University Press.

Green Finance Task Force (2018), 'Accelerating Green Finance', UK Government & City of London, March. <https://www.gov.uk/government/publications/accelerating-green-finance-green-finance-taskforce-report> [Accessed 11/2/19]

H M Treasury (2018), Remit for the Monetary Policy Committee attached to a letter from the Chancellor of the Exchequer to the Governor of the Bank of England.  
[https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/752077/PU2207\\_MPC\\_remit\\_web.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/752077/PU2207_MPC_remit_web.pdf) [Accessed 17/2/19]

Hornbeck, R (2012), 'The Enduring Impact of the American Dust Bowl: Short and Long Run Adjustments to Environmental Catastrophe' *American Economic Review* 102 (4), 1477-1507.

Huan Peng, Xiaoqing Lu, and Chaobo Zhou, (2018), 'Introduction to China's Green Finance System', *Journal of Social Science and Management*, 11, 94-100, 96.

Hutley, N and Hartford Davies S (2016), 'Climate Change and Directors' Duties'. Memorandum of Opinion published by The Centre for Policy Development and the Future Business Council via Minter Ellison, Solicitors, Melbourne, October. <https://cpd.org.au/wp-content/uploads/2016/10/Legal-Opinion-on-Climate-Change-and-Directors-Duties.pdf>  
[Accessed 11/2/19]

International Monetary Fund (2018), 'Annual Report on Exchange Arrangements and Exchange Restrictions 2017'. <https://www.imf.org/en/Publications/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions/Issues/2018/08/10/Annual-Report-on-Exchange-Arrangements-and-Exchange-Restrictions-2017-44930> [Accessed 11/2/19]

International Panel on Climate Change (2007), 'Climate Change 2007: Synthesis Report', Geneva. [https://www.ipcc.ch/site/assets/uploads/2018/02/ar4\\_syr\\_full\\_report.pdf](https://www.ipcc.ch/site/assets/uploads/2018/02/ar4_syr_full_report.pdf)  
[Accessed 27/3/19]

International Panel on Climate Change (2013), 'Climate Change 2013: The Physical Science Basis', Geneva.  
[http://www.climatechange2013.org/images/report/WG1AR5\\_ALL\\_FINAL.pdf](http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf)  
[Accessed 27/3/19]

International Panel on Climate Change (2014a), '*Climate Change 2014: Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects*', Geneva.

[https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA\\_FINAL.pdf](https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf)

[Accessed 27/3/19]

International Panel on Climate Change (2014b), '*Climate Change 2014: Impacts, Adaptation, and Vulnerability, Part B: Regional Aspects*', Geneva.

[https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartB\\_FINAL.pdf](https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartB_FINAL.pdf)

[Accessed 27/3/19]

International Panel on Climate Change (2014c), '*Climate Change 2014: Mitigation of Climate Change*', Geneva. [https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc\\_wg3\\_ar5\\_full.pdf](https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf)

[Accessed 27/3/19]

International Panel on Climate Change (2014d), '*Climate Change 2014: Synthesis Report*', Geneva [https://archive.ipcc.ch/pdf/assessment-report/ar5/syr/SYR\\_AR5\\_FINAL\\_full\\_wcover.pdf](https://archive.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf)

[Accessed 27/3/19]

International Panel on Climate Change (2018) '*Global warming of 1.5° C: Summary for Policymakers*'. Geneva

[https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15\\_SPM\\_version\\_stand\\_alone\\_LR.pdf](https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15_SPM_version_stand_alone_LR.pdf) [Accessed 27/3/19]

Lambert, C, Noth, F, and Schüwer, U (2017), 'How Do Banks React to Increased Credit Risk? Evidence from Hurricane Katrina', SAFE Working Paper No. 94, Goethe University Frankfurt.

[https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2585521](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2585521) [Accessed 25/3/19]

Landon-Lane J, Rockoff H, Steckel R H (2011), '*Droughts, Floods and Financial Distress in the United States.*' pp 73-84, in Libekap GD and Steckel RH (eds) '*The Economics of Climate Change: Adaptations Past and Present*', The University of Chicago Press.

Lloyd's (2014), '*Catastrophe modelling and climate change*', Lloyd's of London.

<https://www.lloyds.com/news-and-risk-insight/risk-reports/library/natural-environment/catastrophe-modelling-and-climate-change> [Accessed 15/2/19]

Nordhaus, W D (2013), *The Climate Casino: Risk, Uncertainty, and Economics for a Warming World*, Yale University Press, New Haven CT.

People's Bank of China (2015) *Notice on Green Financial Bonds*, PBOC Document No. 39.

[https://www.climatebonds.net/files/files/China\\_Annual\\_Report\\_2017\\_English.pdf](https://www.climatebonds.net/files/files/China_Annual_Report_2017_English.pdf)

[Accessed 31/3/19]

Prudential Regulation Authority (2015), '*The impact of climate change on the UK insurance sector, a climate change adaption report by the Prudential Regulation Authority*',

September. <https://www.bankofengland.co.uk/prudential-regulation/publication/2015/the-impact-of-climate-change-on-the-uk-insurance-sector> [Accessed 11/2/19]

Prudential Regulation Authority (2018a), '*Transition in thinking: The impact of climate change on the UK banking sector*', September.

<https://www.bankofengland.co.uk/prudential-regulation/publication/2018/transition-in-thinking-the-impact-of-climate-change-on-the-uk-banking-sector> [Accessed 11/2/19]

Prudential Regulation Authority (2018b), '*Enhancing banks' and insurers' approaches to managing the financial risks from climate change*, Consultation Paper 23/18.

<https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/consultation-paper/2018/cp2318.pdf?la=en&hash=8663D2D47A725C395F71FD5688E5667399C48E08>  
[Accessed 24/1/19]

Reuters, (2014), '*Euro banknotes will remain paper not plastic*'.

<https://www.reuters.com/article/us-euro-fakes/euro-banknotes-will-remain-paper-not-plastic-idUSBREA0C0JQ20140113>. [Accessed 17/2/19]

Rockström, J., Steffen, W, Noone, K, Persson, Å, Chapin, F S III, Lambin, E, Lenton, T M, Scheffer, M, Folke, C, Schellnhuber, H J, Nykvist, B, De Wit, C A, Hughes, T, van der Leeuw, S, Rodhe, H, Sörlin, S, Snyder, P K, Costanza, R, Svedin, U, Falkenmark, M, Karlberg, L, Corell, R W, Fabry V J, Hansen, J, Walker, B, Liverman, D, Richardson, K, Crutzen, P, and Foley, J (2009), *Planetary boundaries: exploring the safe operating space for humanity*. Ecology and Society 14(2): 32.

<https://www.stockholmresilience.org/download/18.8615c78125078c8d3380002197/1459560331662/ES-2009-3180.pdf> [Accessed 25/3/19]

Schoenmaker, D (2018), '*Greening Monetary policy*' Paper prepared for the Bundesbank-NGFS-CEP Conference on "Scaling up Green Finance: The Role of Central Banks", Berlin, 8-9 November 2018. [https://www.cepweb.org/wp-content/uploads/2018/11/Schoenmaker\\_Paper.pdf](https://www.cepweb.org/wp-content/uploads/2018/11/Schoenmaker_Paper.pdf) [Accessed 17/2/19]

Scott, M, van Huizen, J, and Jung, C (2017), '*The Bank of England's response to climate change*', Quarterly Bulletin Q2, 98-108. <https://www.bankofengland.co.uk/quarterly-bulletin/2017/q2/the-banks-response-to-climate-change> [Accessed 27/3/19]

Stern, N (2006), '*The Economics of Climate Change: The Stern Review*', Cambridge University Press, Cambridge.

[https://webarchive.nationalarchives.gov.uk/20100407172811/http://www.hm-treasury.gov.uk/stern\\_review\\_report.htm](https://webarchive.nationalarchives.gov.uk/20100407172811/http://www.hm-treasury.gov.uk/stern_review_report.htm) [Accessed 15/2/19]

Sullivan, R; Martindale, W, Feller E, and Bordon, A (2015), '*Fiduciary Duty in the 21st Century*', UNEP and PRI project report, September.

[https://www.unepfi.org/fileadmin/documents/fiduciary\\_duty\\_21st\\_century.pdf](https://www.unepfi.org/fileadmin/documents/fiduciary_duty_21st_century.pdf)  
[Accessed 27/3/19]

Task Force on Climate-Related Financial Disclosures (2017), '*Final Report: Recommendations of the Task Force on Climate-related Financial Disclosures*', FSB, June. <https://www.fsb-tcfd.org/publications/final-recommendations-report/> [Accessed 15/2/19]

Task Force on Climate-Related Financial Disclosures, (2018), '*2018 Status Report (September 2018)*', FSB, September. <https://www.fsb-tcfd.org/publications/tcfd-2018-status-report/>  
[Accessed 15/2/19]

UNEP FI & PRI (2011), 'Universal Ownership: Why environmental externalities matter to institutional investors', United Nations Environment Programme Finance Initiative and Principles for Responsible Investment.

[https://www.unepfi.org/fileadmin/documents/universal\\_ownership\\_full.pdf](https://www.unepfi.org/fileadmin/documents/universal_ownership_full.pdf)

[Accessed 25/03/19]

World Economic Forum (2010), '*Global Risks 2010: A Global Risk Network Report*', Geneva, January. <http://afyonluoglu.org/PublicWebFiles/Reports-CS/WEF-GRR/2010%20WEF%20Global%20Risks%20Report%2005-2010.pdf>

[Accessed 27/3/19]

World Economic Forum (2013), '*The Green Investment Report - The ways and means to unlock private finance for green growth.*', Geneva.

[http://www3.weforum.org/docs/WEF\\_GreenInvestment\\_Report\\_2013.pdf](http://www3.weforum.org/docs/WEF_GreenInvestment_Report_2013.pdf)

[Accessed 25/3/19]

World Economic Forum (2019), '*The Global Risks Report 2019*', Geneva, January.

[http://www3.weforum.org/docs/WEF\\_Global\\_Risks\\_Report\\_2019.pdf](http://www3.weforum.org/docs/WEF_Global_Risks_Report_2019.pdf) [Accessed 13/3/19]

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