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Risk of capital flight due to a better understanding of climate change

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17 January 2020

Question

What is the evidence on the risk of capital flight in vulnerable countries due to a better understanding of physical climate change risks?

Contents

1. Summary

The physical risks of climate change, including both gradual global warming and an increase in extreme weather events, are likely to cause increasing financial and economic losses. Lower and middle income countries may be more vulnerable to physical risks due to their reliance on climate sensitive economic sectors and their limited capacity to absorb economic losses. However, vulnerable regions in developed countries are also at risk and impacts will also be felt through the global nature of many supply chains.

Economic risks and impacts due to the physical risks of climate change include demand and supply-side losses, reductions in economic growth, destruction of public and private capital and output losses. Impacts will be experienced at the macro-economic level as well as by individual actors such as companies and investors. Consequently, policy-makers, investors and companies will all play a role in responding to the growing financial threat from climate change (MacWilliams et al., 2019).

Despite the potential economic losses and the likelihood that all investments and asset classes are exposed to the physical risks of climate change to some degree, few actors in the financial sector are incorporating physical risks into decision-making. The Task Force on Climate Related Financial Disclosures (TCFD), launched in 2015, has developed a series of recommendations for companies to disclose their climate related risks. Investors can then use this information to make informed capital allocation decisions. The TCFD argue that increased transparency around climate change risks will lead to more efficient markets and more stable and resilient economies[1]. However, it is also possible that a better understanding of physical risks could lead to capital flight from risk-exposed investments and a lack of access to finance for those who need it most.

Findings

There are challenges in assessing physical risks. It is possible to assess the immediate costs of changing weather patterns and more frequent and intense natural disasters, but translating this into expected future risks is difficult (Grippa et al., 2019; Miller & Swann, 2019). There is also an assumption amongst actors that climate risk is owned by governments, which may make it difficult to integrate physical risks into financial decision-making.

This rapid review did not locate any examples of capital flight from developing countries due to a better understanding of the physical risks of climate change. Standard & Poor's (2014) argue that climate change risks are likely to have a negative impact on sovereign credit ratings. Lower rated sovereigns also appear to be more vulnerable to climate change.

Evidence from the Bank of Italy suggests that banks are restricting lending to small and medium sized Italian firms that are exposed to flood risk (Faiella & Natoli, 2018). In contrast, the market response to Pacific Gas & Electric's (a California, USA investor-owned utility company) bankruptcy suggests that it has not caused imminent concern about climate change risks in the utility sector (MacWilliams et al., 2019).

[1] https://www.fsb-tcfd.org/about/# [accessed 17/01/2020].

The physical risks of climate change will differentially affect businesses and the financial performance of sectors, and as well as creating risks, could also create opportunities for investors (UNEP FI, 2018). A small body of commentators argue that physical risks create opportunities for investment, including in resilient infrastructure. A better understanding of physical risks could also lead to more efficient investment and allocation of capital.

Potential mechanisms for building resilience to natural disasters and facilitating recovery following a disaster could help vulnerable countries and regions adapt to the physical risks of climate change. Mechanisms discussed in the literature include:

- **Investing in resilient infrastructure:** Marto et al. (2017) find that investments in adaptation infrastructure lead to reductions in the magnitude of economic damage following a natural disaster, as well as reduced risk of debt distress.
- **Sovereign risk insurance:** Bevan and Adam (2016) find that insurance may or may not be helpful depending on detailed circumstances, with the value of insurance being highest when the worst case disaster materialises. The benefits of insurance must also be weighed against the carrying costs and the conditions of the contract.
- **Bond financing:** Mittnik et al. (2019) find that bond financing can accelerate recovery and it can lead to output, consumption and private and public capital rising again following a disaster. It can also help to reduce the frequency and severity of natural disasters through financing adaptation. However, there may be limitations to bond issuing and credit expansion in low income countries, particularly small countries.

Evidence base

The evidence base for this request was extremely limited. Only one report produced for the United Nations Environment Programme's Finance Initiative directly addressed the risk of capital flight. This review found small but growing bodies of literature on the macro-economic risks of climate change; the economic consequences of extreme weather events; policy options for improving resilience to and recovery following an extreme weather event; and, climate change as an opportunity for investors. This report undertook a series of keyword searches and review of relevant websites including the IMF, the World Bank, the Bank of England, and credit rating agencies amongst others.

2. Physical climate change risks

Physical risks of climate change can be defined as: "those risks that arise from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability of exposure of human and natural systems, including their ability to adapt" (Batten et al., 2016, quoted in Miller & Swann, 2019: 5). A risk has three components: a hazard (an event with the potential to cause harm); probability (can be assigned to the frequency of a given hazard or a given socio-economic consequence); and, vulnerability (the outcomes of climate hazards in terms of their cost) (Batten, 2018).

Physical risks arise from two main sources: gradual global warming, and an increase in extreme weather events (Miller & Swann, 2019: 5). The TCFD categorises the physical risks of climate change into (IIGCC, 2019: 28):

- **Acute risks**: Event driven risks, including increased severity of extreme weather events, such as cyclones, hurricanes or floods.
- **Chronic risks**: Longer term shifts in climate patterns, such as changes in precipitation patterns, rising mean temperatures, or rising sea levels.

Climate change will increase the frequency and intensity of natural disasters including cyclones and hurricanes (Marto et al., 2019).

Low income countries

Lower and middle income economies are typically more vulnerable to physical risks (Grippa et al., 2019). This is due to their reliance on agricultural production and employment, and their vulnerability to climate related natural disasters combined with their weaker capacity to absorb the financial cost (Standard & Poor's, 2014; Mittnik et al., 2019; Marto et al., 2017).). Marto et al. (2019) argue that small developing states are often more frequently hit by extreme weather events than larger countries and their economic costs are often much larger (Marto et al., 2017).

Low income countries have limited economic and financial capacity to adapt to climate change or respond to extreme weather events (Mittnik et al., 2019; Marto et al., 2017). Extreme weather events involve both direct losses of public capital and indirect losses due to reduced output (Bevan & Adam, 2016). Some estimates suggest that indirect losses might be even greater than direct losses for low income countries (Mittnik et al., 2019). The speed at which public capital stock is restored post-disaster plays a decisive role in determining the recovery in private output and consumption (Bevan & Adam, 2016: 1). Small disaster-prone countries may find it difficult to access external debt markets following a natural disaster (Bevan & Adam, 2016).

Vulnerabilities can interact to pose severe challenges for developing countries (Marto et al., 2017). For example, natural disaster risk in Vanuatu interacts with the cumulative impact of non-extreme but prolonged weather events such as El Nino droughts and La Nina's heavy rainfall, and other chronic risks of climate change including sea level rise and coastal erosion (Marto et al., 2017). The probability of a natural disaster happening in Vanuatu in any given year is 65% and more than 99% in a five year period (Marto et al., 2017). In 2015, Cyclone Pam hit Vanuatu causing losses of approximately 60% of GDP and affecting more than 188,000 inhabitants (more than 70% of the population) (Marto et al., 2017). Losses in key productive sectors included damage to tourism and transport infrastructure estimated at 11% of GDP and production losses in agriculture and tourism equivalent to 14% of GDP (Marto et al., 2017).

Economic impacts of physical risks

Both acute and chronic risks are already causing financial and economic losses in both developing and developed economies (Miller & Swann, 2019: 10). For example, economic losses due to weather and climate related extremes in EU member states was almost half a trillion Euros between 1980 and 2017 (Levick, 2019). Losses from extreme weather events have steadily increased since the early 1980s, most significantly in Asia and North America (Standard & Poor's, 2014). Insurance is likely to become more expensive, or even unavailable in at-risk areas of the world, as losses from natural disasters increase (Grippa et al., 2019: 27).

Acute risks are likely to cause immediate economic damage through unanticipated shocks to components of demand and supply, which could last into the medium term (Batten, 2018). Extreme weather events cause physical damage to infrastructure, agriculture and property (Grippa et al., 2019). This damage has a number of effects including: increasing insurance premiums; disrupting businesses; reducing business investment; affecting global supply chains; increasing costs to stakeholders; reducing the longevity and efficiency of physical capital; exposing certain sectors to losses in value (e.g. coastal real estate); and reductions in bilateral trade (IIGCC, 2019: 29; Grippa et al., 2019; MacWilliams et al., 2019; Batten, 2018). For example, public infrastructure networks such as transport, energy and water supply are characterised by complex supply chains that rely heavily on international infrastructure, and are therefore inherently vulnerable to disruptions caused by weather events across the globe (Batten, 2018).

Economic damage from chronic risks are likely to manifest over the longer term through impacts on potential productive capacity and economic growth (Batten, 2018). For example, higher temperatures can cause economic losses through reductions in productivity of workers and agricultural crops (Batten, 2018). Companies' financial performance may also be affected by changes in water availability, sourcing and quality, food security and extreme temperature changes, which affect an organisation's property, operations, supply chains, transport needs, and employee safety (Miller & Swann, 2019: 5). There is an emerging consensus within the climate change economics literature that changing temperatures will have a direct impact of the level of GDP growth (Batten, 2018).

The physical risks of climate change could have a number of direct and indirect losses on the financial sector. Haley (2019) states that there are USD 1 trillion of company assets at risk over the next five years due to climate change, with the financial services industry accounting for 80% of that exposure. Direct losses come from financial institutions exposure to companies, households and countries that experience climate shocks. Indirect losses come from the effects of climate change on the wider economy.

Potential impacts on the financial sector include (Grippa et al., 2019; Batten, 2018):

- Market losses (equities, bonds and commodities), credit losses (residential and corporate loans), and underwriting losses.
- Greater risk in mortgage portfolios due to rising sea levels.
- Tighter financial conditions if banks reduce lending, in particular when climate shocks affect many institutions simultaneously.
- Banks, insurers and reinsurers may become less diversified as climate change can increase the likelihood or impact of events previously considered uncorrelated, for example droughts and floods.
- Financial stability concerns if asset prices adjust rapidly to reflect unexpected realisations of physical risks.
- Inflationary pressures if an extreme weather event leads to a decline in the supply of goods or a productivity shock.

3. Incorporating physical risk into financial decision-making

Few in the financial sector are incorporating physical climate risks into investment decision-making (Miller & Swann, 2019). Whilst knowledge of how physical risks impact risks and opportunities is rapidly evolving, clear risk management practices are still nascent (Miller & Swann, 2019: 8). Physical climate risk is inherent to all investments and financial asset classes (Miller & Swann, 2019). Understanding and internalising that risk into financial decision-making could both reduce exposure to risk and identify opportunities to invest in resilience (Miller & Swann, 2019).

Challenges in assessing physical risk and economic impacts

Assessing physical climate risks and their implications for financial actors and the financial system can be complicated (Miller & Swann, 2019). Physical climate risks involve specific hazards in a specific physical location; the various financial implications of a hazard partly depend on the circumstances of the company or client including its own financial health and ability to withstand financial impacts from business interruption; and, anticipating the timeframe over which physical climate risks will become material (Miller & Swann, 2019). Understanding how these risks impact investment requires understanding risks across a number of different time horizons including the timeframe of asset life and the timeframe of financial exposure (Miller & Swann, 2019).

Climate change externality is different to other types of externalities, which makes it difficult to assess its macro-economic impacts (Batten, 2018). Challenges for assessing its macro-economic impacts include: climate change is global in causes and consequences; its impacts are long-term and persistent; there are pervasive uncertainties about its economic impacts; and, there is a serious risk of major, irreversible change (Batten, 2018).

Climate economics is beset with uncertainty (Batten, 2018). This includes uncertainty around the ability to accurately model the impact of climate change on society and the economy; the future ability of societies to adapt to climate change and the effect of technological change on future greenhouse gas (GHG) emissions; and, around the discount rate used in modelling work to aggregate costs and benefits occurring at different points in time (Batten, 2018). As GHGs persist in the atmosphere for a century or more, the costs of climate change and the benefits of mitigation must be measured over a longer timescale than for other socio-economic issues (Batten, 2018).

Quantifying the link between the likelihood of extreme outcomes and catastrophic damages can depend on the definition of vulnerability (Mittnik et al., 2019: 34). The link between GHG emissions and temperature rise may increase vulnerability to disaster (Mittnik et al., 2019). But, vulnerability is also defined by how much adaptation has taken place and how effective it has been (Mittnik et al., 2019:34). Consequently, increased frequency of climate disasters could be accompanied by a lower severity due to successful adaptation policy (Mittnik et al., 2019).

Ownership of climate risk

The absence of clear ownership of climate risk in many sectors also leads to expectations of publicly funded assistance following extreme weather events/natural disasters (Miller &

Swann, 2019: 8). This further discourages investment in resilience (Miller & Swann, 2019: 8). For example, many developing countries operate on the assumption that climate change related disasters will be addressed through international aid after the disaster (Miller & Swann, 2019).

Miller & Swann (2019) argue that **there is a perception that governments and the public balance sheet are the backstop for climate risks.** This reinforces a perception that climate risk is 'owned' or borne by public balance sheets especially as governments are typically the only source of funding for disaster risk relief and management (Miller & Swann, 2019). There is a lack of incentives in the financial system for good climate risk management, either through fully pricing climate risks in or through policy directives requiring information disclosure (Miller & Swann, 2019). This is likely to increase pressure on public budgets to absorb the costs of climate risks, even though they may not be able to (Miller & Swann, 2019).

4. Physical risk and capital flight

Improving the availability of risk data and understanding of exposure to the physical risks of climate change, and identifying the financial implications of climate risks, could have two potential outcomes (Levick, 2019; Miller & Swann, 2019: 8):

- It could lead to more efficient and stable financial markets and **more effective investment**, as well enormous opportunities for profitable investment by all types of investors including public and private finance.
- It could lead to **capital flight** from risk-exposed investments and a lack of access to finance for those who need it most.

Capital flight

Understanding the financial risks from climate change has the potential to influence capital flows, including capital shifts and capital flight from areas where investment is most needed (Miller & Swann, 2019: 22). A better understanding of the links between physical climate change and financial risks could lead to climate change risk being efficiently priced in to finance (Miller & Swann, 2019). A 2019 report prepared by the Climate Finance Advisors for the United Nations Environment Programme Finance Initiative (UNEP FI) and the Global Commission of Adaptation argues that this could lead to financial flight from some types of investment, particularly of private capital (Miller & Swann, 2019: 22).

Markets could come to perceive investments in communities and countries that are highly vulnerable to climate change as too risky (Miller & Swann, 2019). A 2015 report undertaken by the University of Cambridge argues that changes in the behaviour of regulators and financial markets will accelerate as the physical impacts of climate change intensify (CISL, 2015). Markets could seek to shed at risk assets (CISL, 2015). Scenario analysis in CISL (2015) suggests that climate change entails 'unhedgeable risks" for investment portfolios as changing asset allocations combined with investing in sectors exhibiting low climate risk can offset only half of the negative impacts of climate change on financial portfolios.

Shifts in market perceptions could have implications for development banks, development finance institutions and domestic financing institutions (Miller & Swann, 2019). These organisations have a mandate to accelerate development, including through catalysing private investment (Miller & Swann, 2019). A better understanding of the physical risks of climate change could lead to these institutions needing to leverage their balance sheets more to incentivise private investment (Miller & Swann, 2019). This could place pressure on their credit ratings and eventually on public budgets that are already stretched thin in some countries (Miller & Swann, 2019: 23).

Capital flight from developing countries could have major economic consequences (Miller & Swann, 2019). These include placing additional pressure on public balance sheets, which alone cannot bear the costs of climate risk (Miller & Swann, 2019).

The risk of capital flight is likely to vary due to locations' vulnerabilities to the physical risks of climate change and the type of investment and investors (Miller & Swann, 2019). For example, for some listed equities the presence of climate risk may have little impact on their capacity to invest or attract capital in the short-term (Miller & Swann, 2019). Some private capital may not flee but rather require greater returns, which could be attractive to some investors, or it could internalise climate risk into pricing for the short-term and focus on short-term returns (Miller & Swann, 2019). The availability of finance could also vary by sector and market (Miller & Swann, 2019).

Risks to sovereign creditworthiness

Climate change is likely to negatively impact sovereign creditworthiness in most cases (Standard & Poor's, 2014)[2]. Impacts on creditworthiness will be felt through channels including economic growth, external performance and public finances (Standard & Poor's, 2014). Standard & Poor's (2014) argue that climate change is a global mega-trend that will put downward pressure on sovereign ratings:

- **Economic growth**: climate change is likely to negatively impact national welfare and economic growth potential. Observations corroborating this expectation could lead Standard & Poor's to lower sovereign ratings on the most affected sovereigns.
- **Public finances**: negative impacts on growth as well as the costs of disaster recovery, emergency support and reconstruction following an extreme weather event are likely to put pressure on national budgets. This could potentially put downward pressure on sovereign ratings as debts and deficits rise.
- **External performance**: climate change may put pressure on a sovereign's external accounts in a number of ways including undermining the export base (for countries who depend on exports of agricultural products for foreign currency) and threatening foreign reserves as trade imbalances rise; bad harvests leading to food imports; and, if global food production stagnates, prices for agricultural goods would permanently increase. Increasing pressure on external accounts could in turn increase the downside risks for sovereign ratings.

[2] It is important to note that a number of factors are accessed to determine a sovereign's credit rating including institutional and governance effectiveness, and different credit rating agencies will use different methodologies. Standard & Poor's are highlighted here as the cited report was the only example of the links between climate change and sovereign credit rating that could be found during the course of this review. Standard & Poor's (2014) argue that the significance of climate change in accessing climate risk will increase over the coming decades as evidence of it economic implications become more visible.

Lower rated sovereigns appear more exposed to climate change (Standard & Poor's, 2014). Standard & Poor's (2014) use a composite of three variables to measure the vulnerability of individual sovereigns. These three variables are: share of the population living in coastal areas below five metres of altitude; share of agriculture in national GDP; and, the Notre Dame University Global Adaptation Index (ND-GAIN) which measures the degree to which a system is susceptible to and unable to cope with the adverse effects of climate change (Standard & Poor's, 2014).

Information for all three variables was available for 116 sovereigns. An overall rank of vulnerability was assigned based on ranking the sum of the three ranks for each of the three indicators (Standard & Poor's, 2014). Overall rankings run from 116 (the most vulnerable to climate change) to 1 (the least vulnerable to climate change). Findings include (Standard & Poor's, 2014: 9-10):

- Lower rated sovereigns tend on average to be more vulnerable than higher rated sovereigns.
- The average vulnerability rank of AAA rated sovereigns is 18, whilst for B rated sovereigns it is 84.
- This indicates that over a long time horizon, climate change could contribute to diverging ratings. Sovereign ratings could diverge further if the lowest-rated sovereigns do in fact experience the greatest impact from changing weather patterns and rising sea levels.
- The most vulnerable sovereigns also tend to be poorer, which makes it challenging for them to invest in mitigation measures that would help them adapt to climate change. All of the sovereigns in the top 20 most vulnerable are emerging markets and almost all of them in Africa and Asia. In contrast the bottom 20 least vulnerable group is dominated by advanced economies.

Opportunities

A better understanding of the physical risks of climate change could also lead to new business models and opportunities for profitable investment (Miller & Swann, 2019). This includes insurance and other financial mechanisms which could help countries vulnerable to climate change attract investment capital (Miller & Swann, 2019). The TCFD's 2017 report includes the development of insurance risk solutions as a climate change related opportunity. Related to this there would be market opportunities in terms of access to new assets and locations needing insurance coverage (TCFD, 2017). A better understanding of the physical risks could also potentially increase the demand for financial products and services to help manage or adapt to the risks (UNEP FI, 2018). For example, in the retail mortgage sector there could be an increase in the demand for loans for home improvements for cooling homes in areas where this previously has not been needed (UNEP FI, 2018). In the agricultural sector, farmers may change their business models and move into alternative crops (UNEP FI, 2018).

Climate resilient infrastructure is a key opportunity (Haley, 2019). Whilst investment in resilient infrastructure may be more expensive, it will deliver more sustainable infrastructure in the long-run (Haley, 2019). Estimates suggests that an average of 3% additional upfront capital investment is required to build resilience into infrastructure (Haley, 2019). However, every USD 1 invested in resilience generates USD 4 in economic value (Haley, 2019). A better understanding of climate change could also prevent capital flight as risks will be accurately priced into infrastructure projects, as well as helping vulnerable geographies attract the right kind of investments (Haley, 2019).

Haley (2019) argues that the lack of climate risk standards has resulted in an inefficient allocation of capital with regards to protecting assets from physical climate risks. A better understanding of climate change will enable effective quantification and pricing of physical risks as well as mitigate future human and financial disasters (Haley, 2019).

Integrating climate resilience into project development makes investments both robust and long term, which is a clear advantage for private investors (Miller & Swann, 2019: 6). Examples include offshore wind farms in tropical regions that are able to survive hurricanes or typhoons, or investments in low-cost products to cool buildings (Miller & Swann, 2019: 6).

Awareness of the physical risks of climate change and potential related opportunities appear to be growing amongst investors. In addition to the TCFD, the Institutional Investors Group on Climate Change (IIGCC) formed in 2006 and the Coalition for Climate Resilient Investment formed in 2019. The IIGCC is a membership body of over 200 European institutional investors overseeing more than EUR 30 trillion in assets globally[3]. The Coalition for Climate Resilient Investment represents 34 companies and organisations with more than USD 5 trillion in assets (Haley, 2019).

5. Measures to address physical risks

Resilient infrastructure

Encouraged by international organisations including the IMF, the World Bank and the African Development Bank, disaster-prone developing countries are focusing on preparation and adaptation (Simison, 2019). The IMF argues that investing in resilience could cut the costs of post-disaster intervention by at least half (Simison, 2019). However, many vulnerable countries may be unable to finance investments in resilience themselves (Simison, 2019).

The increasing frequency and intensity of extreme weather events due to climate change highlights the importance of resilient infrastructure (Marto et al., 2017). Resilient infrastructure includes adaptation infrastructure capital such as seawalls as well climate-proofing roads to withstand stronger natural disasters (Marto et al., 2017). Boosting infrastructure investment is important for economic development (Marto et al., 2017):

> it is critical to be mindful of the trade-offs involved in deciding how much and what type of infrastructure to install and to take mitigating measures where and when necessary. Otherwise, economic and social costs after storms and other climate-related shocks will be unbearable.

Marto et al.'s (2017) small open economy model analyses how small developing states could build resilience to and recover from natural disasters. The model is calibrated to a small, low-income economy and is applied to Vanuatu (Marto et al., 2017). It analyses the feasibility of ex ante policies (building adaptation infrastructure and fiscal buffers), contrasting these with post-

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[3] https://www.iigcc.org/ [accessed 17/10/2020].

disaster support provided by donors (Marto et al., 2017). The model also allows comparison of alternative paths of post-disaster reconstruction including alternative financing modes and their implications for growth and debt sustainability (Marto et al., 2017).

Marto et al.'s (2017) model estimates what could have happened if the government of Vanuatu had spent 3% of GDP per year on adaptation infrastructure in the 5 years prior to 2015's Cyclone Pam. Results include:

- The magnitude of cyclone damage would have been reduced.
- Investments in adaptation would have reduced damage to standard public infrastructure by 5.2% and damage to private capital by 9.7%. Productivity losses in the tradeable and non-tradeable sectors would have been reduced by 3.8% and 3.9% respectively.
- Reduced risk of debt distress: public debt would have reached less than 60% of GDP over the medium term as opposed to 105% of GDP in a scenario where the government does not invest in resilient infrastructure and finances reconstruction from external borrowing.
- Helping the government build resilience also lowers costs for donors as it is cheaper than dealing with the consequences of unmitigated shocks.
- Fiscal buffers, i.e. contingency funds saved by small developing states, may have some value for states that experience relatively frequent events of manageable proportions as these are unlikely to elicit a major response from donors. However, this argument does not apply to truly catastrophic events such as Cyclone Pam. A small developing state could not save enough to deal with a future cataclysmic event without stunting its development. Any money it did save would help to reduce the burden on its donors, but it would not be rational for a developing country to try and save money to its donors.

The role of donor aid

Marto et al. (2017) also model the support needed from the donor community to fund reconstruction following Cyclone Pam. Findings include that the donor community would need to commit significant resources: an additional 50% of pre-cyclone GDP in grants over a period of 15 years after the cyclone (Marto et al., 2017). Despite initial commitments from the international community, which were lower than the levels Marto et al., (2017) estimate were needed, disbursement has not followed suit (Marto et al., 2017). This suggests that the pace of reconstruction will be slower than expected and important infrastructure projects may take more time to materialise (Marto et al., 2017: 20).

Sovereign risk insurance

In the event of a disaster, sovereign risk insurance covers the direct costs of the rebuild, with some market-based insurance being bundled up with technical expertise, which means the rebuild rate may be faster (Bevan & Adam, 2016). However, the benefits of insurance must be weighed against the cost of carrying insurance, which is financed by the domestic tax system (Bevan & Adam, 2016).

High damage hurricanes, for example, are rare events (Bevan & Adam, 2016). Therefore, Bevan and Adam (2016) argue that whether or not it is worthwhile to have insurance depends on the nature of the insurance contract, the economic consequences of the loss of public capital and the expected frequency of high-damage events. Insurers typically charge a high premium so the insurance is not actuarially fair (Bevan & Adam, 2016). Marto et al. (2017: 24) argue that small developing states may see purchasing catastrophe insurance as a wasteful transfer to more developed economies as it could decrease the amount of their post-disaster aid by the size of the insurance pay out.

Modelling sovereign risk insurance

Bevan and Adam (2016) use a dynamic general equilibrium model to examine sovereign disaster risk insurance, increased taxation and budget reallocation as alternative financing mechanisms for reconstruction following a disaster. The model is calibrated using national accounts data and a natural disaster profile for Jamaica, and focuses on the specific risks posed by tropical cyclones (Bevan & Adam, 2016). The model includes simulations for no cyclone, a one-in-10 year intensity cyclone, a one-in-25 year cyclone, a one-in-100 cyclone, and a one-in-500 cyclone (Bevan & Adam, 2016). It is assumed that the economy is exposed to the chosen risk distribution in year 1 but not in subsequent years, i.e. there is no repeated exposure to cyclones after the initial shock (Bevan & Adam, 2016).

Assumptions within the model include that the destruction is entirely concentrated on the public infrastructure capital stock, no direct destruction of private capital or loss of lives or current output occurs as a result of the hazard (Bevan & Adam, 2016). Impact on private capital and consumption occurs solely through the loss of the complementary public infrastructure capital (Bevan & Adam, 2016).

Insurance may or may not be helpful depending on detailed circumstances: the value of insurance is highest when the worst case materialises (Bevan & Adam, 2016). Other key findings include (Bevan & Adam, 2016: 21):

- In the absence of donor grants, tax financing is the best method for financing reconstruction and is always preferable to insurance in an either-or choice. But, this presupposes that increased taxation on the required scale is feasible, which is not always the case.
- Budget reallocation is potentially very damaging, with any diversion of recurrent spending for O&M likely to be very costly and worse than a do-nothing approach.
- The opportunity cost of funds is highly variable; if a tax financing regime were feasible, this might be only around 6%-9%, but if re-allocations from O&M were used, this might be as high as 37%-44%. The opportunity costs of insurance, on the other hand, might fall in the range 12%-15%, higher than the tax alternative, but much lower than the reallocation from O&M.

Bond financing

Bond financing can accelerate recovery and it can lead to output, consumption and private and public capital rising again following a disaster (Mittnik et al., 2019). Mittnik et al. (2019) use a multi-phase dynamic macro model to analyse the macroeconomic effects of rare large disasters arising from climate change and explore the impact of bond financing for building resilience to and recovery from a natural disaster. The model has three phases: phase one, mitigation and adaptation to climate change is financed through taxation. In phase two, the disaster phase, small and large disasters reduce capital stock and increase risk premia for credit financing. During this phase bond financing is added. In phase three, bond issuing ceases and bonds are paid back through a tax rate on income, but the economy may face some persistent effects on risk premia (Mittnik et al., 2019).

Comparing weak and strong shocks, Mittnik et al. (2019) find that:

- For both weak and strong shocks debt rises, and public and private capital is damaged, with the size of capital stocks shrinking, although there are differences in severity.
- Amplified disaster risk and actual disasters affect private and public capital stocks directly; risk premia are detrimentally affected.
- **Weak shock**: the economy can continuously grow with high borrowing, financing climate related infrastructure investments and appropriate mitigation and adaptation policies. Bond financing, used to fund effective mitigation and adaptation policies, generates higher debt, but lower debt-to capital ratios and higher welfare than in it does in relation to strong shocks.
- **Strong shock**: there is a stronger and longer disaster related period with lower growth. Stronger disasters generate smaller expansions of capital stocks and much lower consumption levels. Debt rises steadily due to risk premia increasing.

Mittnik et al. (2019) argue that bond financing can provide funds for, and improve, both adaptation and be effective in rebuilding public infrastructure after a natural disaster. By financing adaptation, bond financing can help to reduce the frequency and severity of natural disasters, help reverse slow long-run climate change impacts and help build early warning systems which can help reduce vulnerability to climate disasters (Mittnik et al., 2019). Green bonds are increasing: municipalities in both the developed and developing world have issued green bonds are a means of raising funds; the World Bank issues bonds for developing countries; and, some investment banks have also developed green bonds (Mittnik et al., 2019).

However, there are limitations to bond issuing and credit expansion in low income countries (Mittnik et al., 2019). For example, small low income countries have restricted opportunity for achieving scale effects from credit expansions and bond issuing (Mitnik et al., 2019).

6. Case studies

Italy

Bank lending to Italian small and medium-sized enterprises is negatively correlated with their flood risk exposure (Faiella & Natoli, 2018). Faiella & Natoli (2018) investigate the relationship between bank lending and catastrophic risk by matching data on flood risk with proprietary data on bank loans at the municipal level. After controlling for sectoral and province level effects, Faiella & Natoli (2018) find that catastrophic risk has a negative effect on bank lending.

A robustness check uses province-level data from a different proprietary dataset, which allows the authors to distinguish between credit granted by small and big banks to small and small firms (Faiella & Natoli, 2018). This robustness check confirms the results for small and medium sized firms (Faiella & Natoli, 2018). Faiella & Natoli (2018) argue that whilst there is no identification of demand and supply drivers of credit, their results suggest that banks can discriminate borrowers based on their catastrophic risk exposure, but only ration credit to small firms, who are less able to diversify risk.

USA

Pacific Gas & Electric

This investor-owned utility company in California, USA filed for bankruptcy in 2019. Commentators have labelled this the 'first climate change bankruptcy' (MacWilliams, 2019). Rapid climatic changes caused prolonged droughts in California, USA (Grippa et al., 2019). This dramatically increased the risk of fires from investor-owned utility company, Pacific Gas and Electric's operations (Grippa et al., 2019). In January 2019 the company estimated it faced liabilities of over USD 30 billion from wildfires in 2017 and 2018 (MacWilliams et al., 2019).

Policy responses can determine how the costs of climate change are allocated (MacWilliams et al., 2019). California state legislation, that came into force in July 2019, combines measures to both mitigate the risks of future fires, and allocate the costs of any future damages (MacWilliams et al., 2019). Mitigation measures include (MacWilliams et al., 2019):

- USD 5 billion of safety investments that utilities are required to make, on which they cannot earn a return on equity.
- The establishment of a Wildfire Safety Advisory Board to review utilities' implementation of specific safety requirements (including having an approved fire mitigation plan and a fire safety committee).
- The Advisory Board advises the California Public Utility Commission on whether to issue utilities with a safety certificate.

The legislation also established a USD 21 billion wildfire insurance fund, capitalised equally through ratepayers and investor-owned utilities' contributions (MacWilliams et al., 2019). A safety certificate is a prerequisite for accessing funding through these mechanisms (MacWilliams et al., 2019). The fund was meant to restore investor confidence[4]. In April 2019, Standard & Poor's threatened to downgrade all of California's utilities to junk status if a new regulatory framework was not adopted (MacWilliams et al., 2019: 26-27).

The creation of the wildfire insurance fund provides important policy lessons for designing comprehensive frameworks for allocating climate damage costs, but there are also potential pitfalls (MacWilliams et al., 2019: 7). The fund and the broader legislation defines utilities' financial exposure for climate damage situations and provides liquidity for utilities to provide essential services when facing large disasters (MacWilliams et al., 2019: 7). The former is beneficial for investors (MacWilliams et al., 2019).

However, the large reserves set aside by the fund will result in higher electricity bills; being unable to earn on a return on safety-related spending may diminish the incentives for proactive climate mitigation investment; and, the fund may be insufficient for future wildfire costs and creates uncertainty about how these costs will be allocated (MacWilliams et al., 2019: 7).

The legislation did not reform the California legal framework that allows utilities to be held liable for damages they did not cause (MacWilliams et al., 2019: 8). This perpetuates risks for companies and ratepayers (MacWilliams et al., 2019). It could create liquidity and other financial

[4] https://www.theguardian.com/business/2019/oct/31/pge-utility-california-wildfires [accessed 13/01/2020].

difficulties for investor-owned utilities even if they are allowed to recover the costs through the wildfire fund (MacWilliams et al., 2019). Cost recovery could take years and create considerable uncertainty that could be reflected in utilities share prices and borrowing costs (MacWilliams et al., 2019).

Market responses to Pacific Gas & Electric's bankruptcy suggest that it has not caused imminent concern about climate risks in the utility sector outside of California (MacWilliams et al., 2019). Reasons for this could include (MacWilliams et al., 2019):

- investors believe that cost increases from climate change will occur too far in the future to materially impact the present value of their investments;
- they may view wildfires as a California-specific risk;
- they may reflect the belief that the costs of climate change in the utility sector will fall on ratepayers, insurance companies and/or taxpayers as opposed to investors;
- they may lack the information or modelling tools to assess the likelihood and geographic dispersion of high-impact tail events such as wildfires.

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Suggested citation

Cooper, R. (2020). *Risk of capital flight due to a better understanding of climate change risks.* K4D Helpdesk Report 727. Brighton, UK: Institute of Development Studies.

About this report

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