Citi GPS

SYSTEMIC RISK

Systemic Solutions for an Increasingly Interconnected World

Citi GPS: Global Perspectives & Solutions

April 2021

Citi Global Insights

Jason Channell
Global Head of Sustainable Finance, Citi Global Insights

+44-20-7986-8661 | jason.channell@citi.com

Elizabeth Curmi
Citi Global Insights

+44-20-7986-6818 | elizabeth.curmi@citi.com

Ying Qin
Citi Global Insights

+44-20-7986-8325 | ying.qin@citi.com

Centre for Risk Studies at the University of Cambridge Judge Business School

Tamara Evan
Lead Geopolitical Risk Research, Centre for Risk Studies

Daniel Ralph
Academic Director, Centre for Risk Studies

Andrew Coburn
Chief Scientist, Centre for Risk Studies

Olivia Majumdar
Risk Associate , Centre for Risk Studies

Expert Interviews

Dame Inga Beale
Former CEO, Lloyd's of London

Mark Carney
UN Special Envoy for Climate Action and Finance, Former Governor of the Bank of England

Publication Citation:
Citi GPS and Cambridge Centre for Risk Studies, *Systemic Risk: Solutions for an Increasingly Interconnected World,* 2021; Citi GPS: Global Perspectives & Solutions and Centre for Risk Studies, University of Cambridge, Judge Business School

With thanks to: ***The Cambridge Centre for Risk Studies Research team***

SYSTEMIC RISK

Systemic Solutions for an Increasingly Interconnected World

Jason Channell
Global Head of Sustainable Finance,
Citi Global Insights

Risk is an ever-present fact of life. Yet as our world becomes more globalized and interconnected, we have inadvertently built systems which have not just the ability to transmit those risks across geographies and turn them from local into global phenomena, but which also have the ability to cause further global crises to materialize. Moreover, these crises are arguably more 'existential' in nature than ever before — have we ever knowingly faced a planetary threat as critical as the one climate change presents?

In the report that follows, we examine the nature of 'systemic risk', identifying a Global Risk Nexus of 10 key systemic risks, from climate change to biodiversity loss and natural disasters, through antimicrobial resistance, human and agricultural pandemics, to cyber risk and global governance failure, and ultimately global economic and financial crises. We also examine the interlinkages between those risks, for example, how climate change can drive biodiversity loss, with the potential to impact global food chains and financial and economic crises.

These risks can seem so overwhelmingly large and complex in their nature, it is easy to become resigned to our powerlessness to understand and quantify them, let alone to try to prevent them. Yet as John Dryden observed in the 17th century, 'It is madness to make fortune the mistress of events, because by herself she is nothing, and is ruled by prudence.' His words ring as true today as they did then — many of the issues facing us are not in fact unprecedented. With a prudent approach we can analyze and quantify them, predict their severity or frequency, and even prevent them.

This report has been written in conjunction with the Centre for Risk Studies at Cambridge University, with further contributions from thought leaders in the world of risk including Dame Inga Beale and Mark Carney. In the report we assess the quantum of systemic risks, their interlinkages, and by examining the barriers to addressing them, propose solutions for not just adapting to them, but to mitigating and even preventing them. We look at how individual entities from corporates and supranationals to sovereigns can analyze and address systemic risk via scenario analysis and stress testing, as well as proposing broader systemic solutions. The very feedback loops which make these risks systemic in their nature can be turned against them, providing positive feedback loops which, by preventing one, can reduce the probability or severity of another. We examine how vast pools of capital could be created and turned to the prevention of the very risks to which they seek to adapt, thereby reducing the probability and severity of those risks.

We identify $3 trillion per year of investment opportunities which could reduce the probability, frequency, and severity of these systemic risks — a vast sum to be sure, but one which pales into insignificance against the tens of trillions of dollars in liabilities which could potentially be avoided. If this argument in itself were not compelling enough, many of the prevention and mitigation measures have the ability to drive economic growth, with significant multiplier effects of up to 15 times. These would be attractive against any economic backdrop, but against the current global economic malaise of secular stagnation and ultra-low returns across all asset classes, it is surely an opportunity we cannot afford to pass up.

We can either worry about the future and deal with it when it comes — if indeed we can — or tackle these risks head on, embrace the very feedback loops which make them systemic, save trillions of dollars, and drive economic growth in the process.

From Identification to Solutions

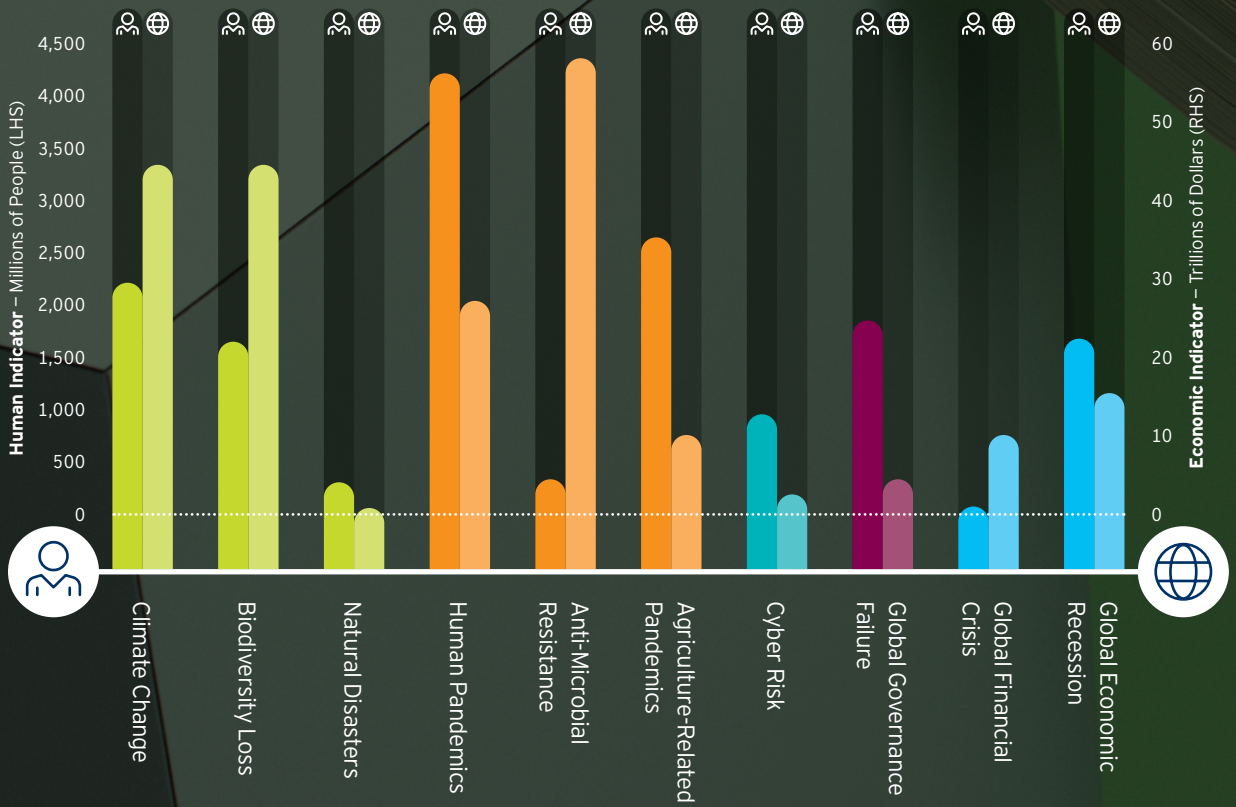
GLOBALIZATION AND INTERCONNECTEDNESS DRIVE SYSTEMIC RISK

Globalization has brought great economic benefits, poverty reduction, and increased interconnectedness. But it has also given rise to systemic risks – or risks that threaten to break down the entire system. In order to prevent or mitigate these risks, we need to identify them. We use three criteria to identify the 'top 10' global systemic risks for our Global Risk Nexus.

Environmental	Climate Change	Biodiversity Loss	Natural Disasters	
Societal	Human Pandemics	Anti-Microbial Resistance	Agriculture-Related Pandemics	
Technological	Cyber Risk			
Geopolitical	Global Governance Failure			
Economic	Global Financial Crisis	Global Economic Recession		

QUANTIFYING THE RISK

The Global Risk Nexus provides comprehensive risk management programs a tool to assess the scale of impact for different risks. Using economic metrics such as Global GDP@Risk, we estimate the human and economic impact of each risk and show the magnitude of impact if we fail to act – billions of people and trillions of dollars are at risk.

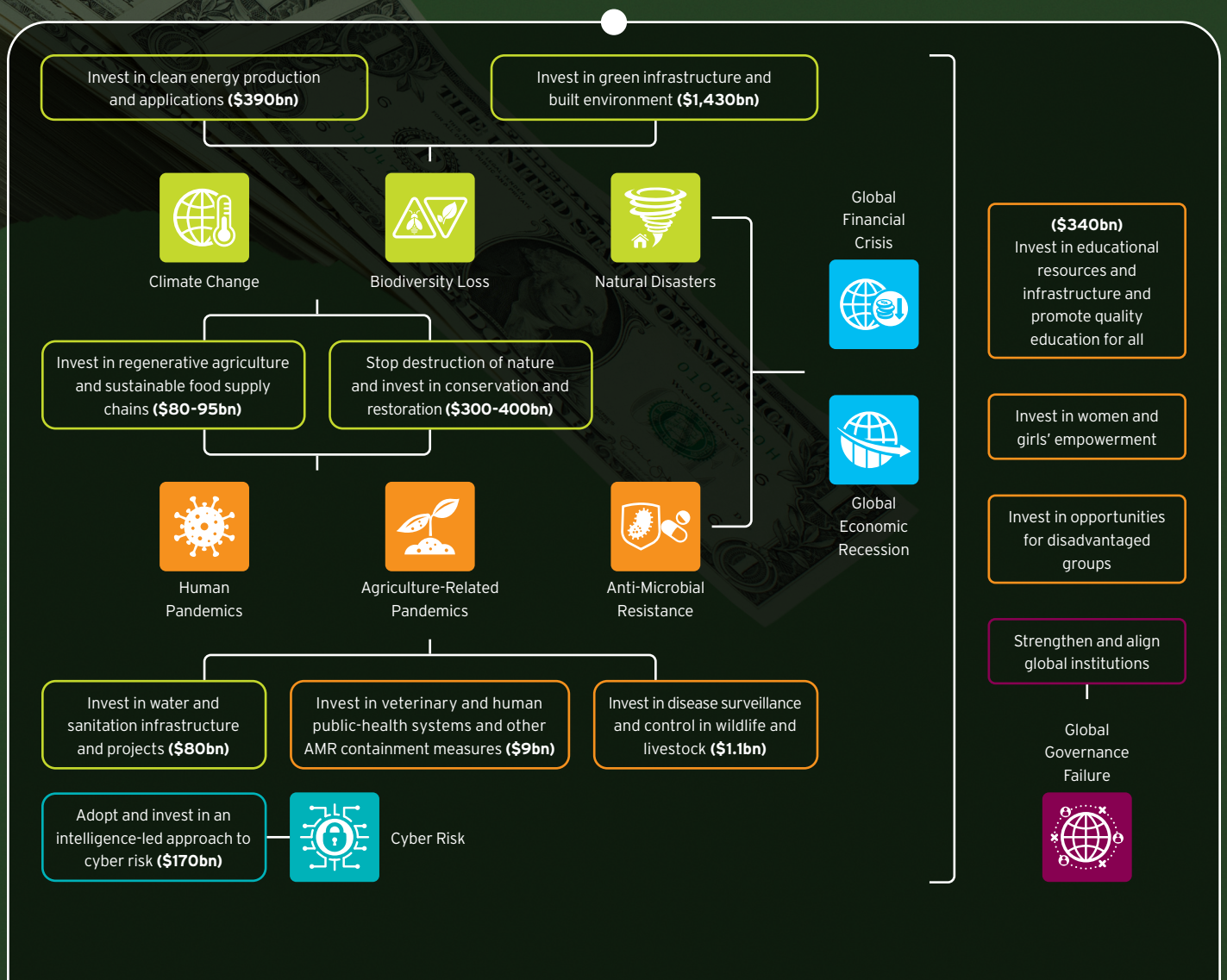


APPROACHES TO ADDRESSING SYSTEMIC RISK

To truly address systemic risk, collective and coordinated action will be required to provide systemic solutions. Finance, working in conjunction with both the private sector and the public sector could create pools of capital to reinvest in prevention of systemic risk.

$3 TRILLION – INVESTMENT WORTH MAKING TO OFFSET RISK

If we add up the annual investment opportunities which could reduce the probability, frequency, and severity of these systemic risks, it comes to almost $3 trillion per year. However, the opportunity to offset hundreds of trillions of dollars in liabilities, for the sake of a $3 trillion investment per year, seems like an investment worth making.



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Section 1: Understanding Systemic Risks

How Has Globalization Changed the Nature of Risk?

The COVID-19 pandemic has brought the strengths and weaknesses of the globalized economy into sharp relief. Invariably, the state of global travel, trade, and business contributed to the spread of the outbreak, and yet it is only through international collaboration, securitization, and mutual support that we will identify solutions to the disease itself, as well as the economic downfall linked to the crisis.

Since the Great Financial Crisis (GFC) in 2007-09, sovereigns, supranationals, and businesses have grown increasingly aware of the active role they can play in limiting and shaping their risk exposure. The significant impact of a potential pandemic to global trade and business continuity had been acknowledged across many industries, if not fully understood or planned for in the early months of 2020. As businesses return to some semblance of normalcy after the pandemic's first stages, the question remains as to how executives, analysts, and strategists can effectively manage their risk planning in the ongoing COVID-19 crisis, and in the face of concatenating or even direr shocks to the economic system.

Throughout this report, we address a broad spread of global scale shocks that can affect businesses and the economy in general, and what can be done to mitigate them now and in the future.

Although each business is exposed to its own catastrophes — a fire in its main manufacturing plant or a lawsuit from a business counterparty — the worst kind of shock, like a pandemic, is 'systemic', i.e. it may affect many organizations at the same time. One example of this phenomena is a credit crisis, where any one company reduces the amount of business it is prepared to do with another, so in turn each of its trading partners reduces their business with their counterparties and the downturn spreads contagiously throughout the entire economy. These systemic shocks are made worse by the very connections that have driven economic growth throughout the 20th century. The globalized nature of the economy can amplify shocks, e.g., the liquidity drought accompanying the Great Financial Crisis, and spread them quicker and wider than ever before to international markets.

Shocks and extreme events, though rare, are recognizable by type and impact throughout history. Where they cause severe impacts to more than one continent, they can be termed 'global shocks' or 'macro-catastrophes'. There are many potential causes of macro-catastrophe: epidemics, financial credit contractions, localized destruction of means of production, and geopolitical disruption to trading systems. It is equally important to identify systemic trends and attendant threats driven by human activity, compounded by the failure of global governance, and exemplified by the twin threats of climate change and biodiversity loss (see further discussion on the 10 systemic risks in the Global Risk Nexus to follow). Managing the risks of disruption from macro-catastrophes is a major concern of government national security, international business, financial services and insurers, and investment managers across the world.

A Recent History of Globalization

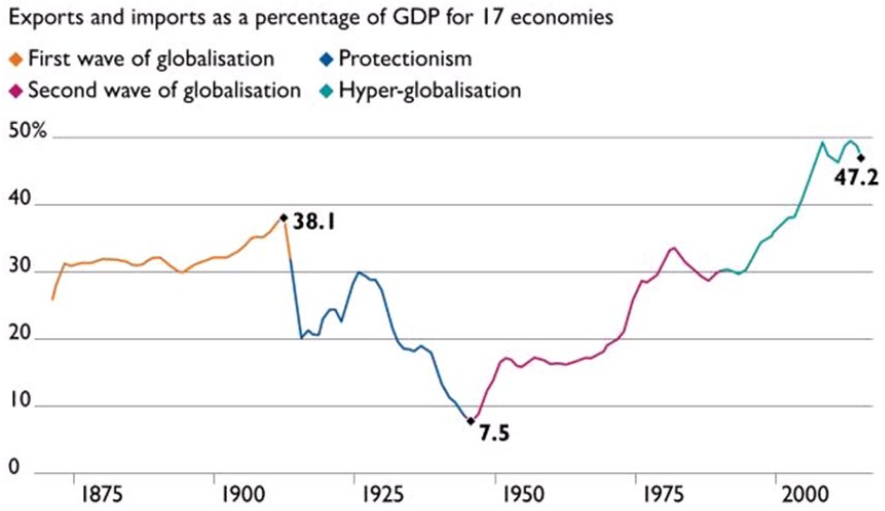
To better understand how globalization has shaped the international economy, and enhanced the risks that economy faces, it is necessary to understand the forces underpinning globalization over the past fifty years and their related economic growth.

Trade is one of the principle drivers of economic growth. The increase in international trade through globalization since the 1980s has fueled one of the greatest increases in living standards in the developed world.

Economic growth, particularly forecasts of future prosperity, is often depicted as a smooth trajectory of inexorable increase. However, the actual path of wealth creation is by no means smooth. Crises and shocks have periodically destroyed economic value throughout history. As investors know, any time series of stock exchange indices shows corrections, bear markets, and reversals as well as bull markets and periods of steady growth.

The current period of globalization is neither unprecedented, nor irreversible. Figure 1 shows the historical cycle of exports and imports as a proportion of the global economy. Trade in the last few decades of the 19th century and the early 20th century was global in character, similar to the world's economy in the late 20th century. The occurrence of the First and Second World War, and the protectionism that arose as a result, reversed globalization for half a century. Arguably, the world now faces renewed challenges of resurgent nationalism, protectionism, and reverses to the international trade relationships that have been the engine of much of the recent growth in the world economy.

Figure 1. Exports and Imports as a Percentage of GDP for 17 Industrialized Nations



Source: NBER, Barclays, Bank of England, Sunday Times[1]

The increase in trade and economic value has influenced many aspects of life in advanced and emerging economies alike, changing conceptions of labor and consumption; industry and production; living standards, and expectations. The result is a world that is increasingly interconnected and interdependent.

This increasing interdependency leads to greater systemic risk exposure, with local shocks generating wider and deeper global ripples. The 1970s' OPEC (Organization of Petroleum Exporting Countries) oil crisis is an iconic example of a commodity shock with global economic consequences: a retaliatory embargo orchestrated by Arab members of OPEC caused global oil prices to skyrocket and led to a recession in the U.S. from 1973 to 1975.

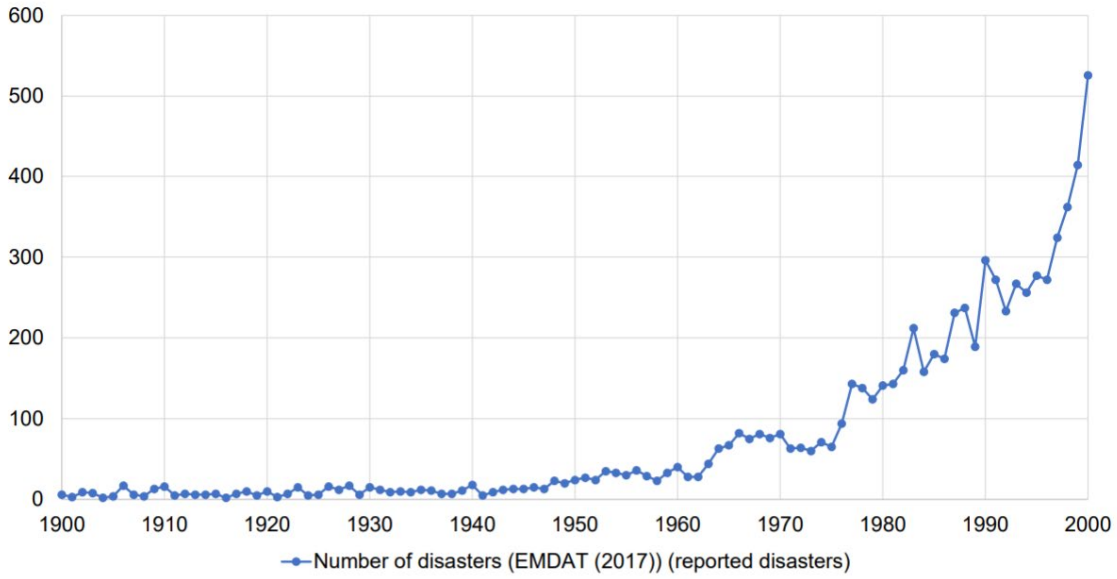
[1] Smith (2017).

The 1997 Asian Financial Crisis exemplifies a regional financial shock with global impacts. Heralded by the collapse of the Thai baht starting in July 1997, the financial crisis spread to Malaysia, the Philippines, and South Korea, sinking regional real GDP growth rates to negative levels into 1998. It also linked to developed economies given that growth rates slumped over two quarters in 1998, by more than 10 percent in the United States, and more than a third in the United Kingdom.[2]

A third and oft-mentioned example, the collapse of the huge Long-Term Capital Management (LTCM) hedge fund, highlights the awareness of systemic risk posed by the international financial system long before the Great Financial Crisis of 2007-09. LTCM was driven to the wall by a combination of the 1997 Asian crisis and the 1998 Russian foreign debt default. LTCM was bailed out by the Federal Reserve Bank of New York to forestall a U.S. and global financial crisis. Indeed, government bailouts in times of crisis are arguably what makes the risk of default bearable by markets.[3]

As a result of a myriad of factors, global risks have changed in their frequency and impact as well as their economic tenacity throughout the 20th century. Disasters, both man-made and natural, now occur more often than at any time in our recent history. The worldwide effects of the Great Depression of the 1930s and the Great Financial Crisis indicate the potency of market crashes in major world economies as they affect the real economy, including wider international prospects. The average period of time between crises from 1700 to 1900 was 21 years; since 1960, the interval has shrunk to just eight.[4] Similarly, the interval between major natural, technological, and geopolitical catastrophes has also shrunk as the impacts of these risks have evolved a global spread.

Figure 2. Number of Disasters Since 1900



Source: Cambridge Centre for Risk Studies, EMDAT (2017)[5]

[2] IMF, International Financial Statistics.
[3] Dialynas (2017).
[4] Needham (2014).
[5] Evan (2019).

In terms of risk characteristics, globalization underpins a risk which is emergent: the world economy is exposed to larger and more systemic threats than previously because more of today's trade is synchronized internationally. Quantifying the impact of this emergence is only one of the challenges, and hence goals, of assessing systemic risk to the global economy.

Cities as Global Economic Powerhouses

The growth of interconnectivity and globalization has seen the rise of cities and urban regions in emerging economies, including the BRICS (Brazil, Russia, India, China, and South Africa) and MINT (Mexico, Indonesia, Nigeria, and Turkey) economies. The rapid increase of global trade has facilitated the development and increased economic output of cities in the developing world — for example, Bangalore in India. Previously a largely agricultural region, the city has been transformed since the 1980s due to the growth and success of the software export industry.[6]

However, this economic success is double-edged: if crises were to hit individual cities such as Bangalore, their reverberations would now be felt throughout the global economy. In Guangdong Province, China, commonly referred to as the "factory of the world", natural catastrophes such as flooding in the Pearl River Delta have threatened not only the region itself but global value chains connected to the region.[7] In Mexico, where 35 percent of the North American automobile trade resides,[8] regional and global politics, including the recent overhaul of the North American Free Trade Agreement (NAFTA) into the United States, Mexico, Canada Agreement (USMCA), potentially add to latent instability and vulnerability both within Mexico and in global value chains that rely on industrial manufacturing in the country.[9]

How Risk Travels Further than Ever Before

A more detailed exploration of a city that has significantly benefited from the rise of globalization and how local disasters can impact the global economy as a whole, is detailed below for the case of Seoul. In our interconnected world, shocks such as the hypothetical scenario of geopolitical conflict, drawing in actors such as South Korea, the U.S., and China, and negatively impacting key global cities such as Seoul, are omnipresent.[10,11]

The entrenchment and deep involvement of Seoul, and in turn South Korea, in global networks of trade — from electronics and consumer goods, to automobiles, shipping and heavy machinery, construction, service industries, and finance — means that a disruption would not just impact the bottom line in Seoul and South Korea, but would instead severely impact global value chains, production processes, and the development of products across the world. This is partly due to how the South Korean economy, and more broadly its society, is ordered.

[6] Kannan (2013).
[7] Kimmelman (2017).
[8] Franco et al. (2016).
[9] Stuart (2018).
[10] Heo et al. (2008).
[11] Kim and Chung (2017).

Seoul Case Study: A Hypothetical Shock and Its Effect on the Global Value Chain

In South Korea, powerful conglomerates known as chaebols[12] exert influence through economic and social capital that rivals the government. Top-tier chaebols, such as Samsung and LG Group, control more than half the total value of the South Korean stock market. Headquartered in Seoul, chaebols operate in an extremely hierarchical manner, with Samsung's Digital City encompassing over thirty-five thousand employees, including over a quarter of all the company's Research and Development staff. The entire operations of Samsung rely on what happens in Seoul while the surrounding areas of Seoul carry the brunt of the company's manufacturing prowess.[13]

Samsung's facilities in Pyeongtaek[14] and other regions south of Seoul, represent some of the world's largest manufacturing facilities for components. As its most profitable division, Samsung dominates the components market, providing top consumer brands with memory chips (40 percent market share) and OLED displays (90 percent market share).[15] A manufacturer like Apple, for example, struggles to diversify away from its near total reliance on Samsung's components.[16] To put Samsung's component business in perspective, expected earnings from the Galaxy S8 are estimated to be lower than the profit made on the components sold for the iPhone 10 alone.[17]

A negative shock to Seoul and the South Korean economy would have a major impact within the region and beyond. One such hypothetical shock could be geopolitical in nature, for example an interstate conflict might easily escalate into a full-blown conflict, impacting Seoul and likely leading to a global economic and consumer goods, especially smartphone, crisis.

With bottlenecking from a lack of supply, global value chains would be unable to fulfil global demand. This would result in the loss of manufacturing capacity and the potential layoffs, literal disappearance of tens of thousands of industry-leading researchers, designers, and engineers. Further devastation to the industry might be felt in aftershocks, such as China's potential entry into the conflict. This would further fracture the global value chain and likely halt any remaining production in the industry.

In our interconnected world, shocks such as a hypothetical geopolitical conflict, drawing in major actors and negatively impacting key global cities, are omnipresent.

[12] Tejada (2017).
[13] Samsung company reports.
[14] Min-hyung (2017).
[15] Samsung company reports.
[16] Hosokawa (2020).
[17] Sin (2017).

Identifying Systemic Risks

Known and Emerging Global Risks

It is commonly claimed that future crises are generally unforeseeable, and the world's complexity means that catastrophic failures and disruption arise randomly with too many potential future permutations to consider. Some have even argued that any kind of expectation and preparedness for future crises is doomed to be defeated by 'black swans': strategic surprises from extreme events outside the realm of regular expectations that are only able to be perceived in retrospect.

This has led to a degree of fatalism towards threat assessment. Due to the difficulty of anticipating rare crises and the need for thorough theoretical understanding of low probability events (often to augment a statistical dataset or historical record), the task of rigorous evaluation of potential future threats has appeared daunting. This is, perhaps, especially so for a shock severe enough to have systemic consequences which can be written off under force majeure as an 'act of God.'

On the contrary, the unexpected nature of catastrophes has more to do with human and organizational perception, specifically the failure to recollect or consider long past events, than to the occurrence of unique or new processes.

It is a worthwhile exercise to consider the fundamental causes of what we call macro-catastrophes, namely, events causing losses on a global scale, or globally systemic shocks. Nearly all macro-catastrophes are caused by a process that has occurred generically before, usually in a different form, or a different location. It is rare for a catastrophe to be completely unprecedented.

The 9/11 al-Qaeda attack is often cited as a 'black swan' although using a plane as a missile was the modus operandi of Japanese Kamikaze pilots in World War II, and the threat of crashing a plane into a building was nearly three decades old in 2001.[18] While the scale and sophistication of the 9/11 attack, and the political and economic consequences that followed, were unexpected by almost everyone, terrorism and acts of political violence have been recorded for centuries.

Likewise, the spread of COVID-19 cannot be reasonably viewed as an unprecedented, or even unexpected catastrophe. Disease has accompanied civilization from its beginning as a consequence of the domestication of animals. The increasing economic power of parts of East Asia throughout the 20th and 21st centuries has contributed to changes in traditional diets, leading to a sharp increase in the number of urban farms in densely populated cities, increasing the risk of zoonotic diseases manifesting in humans. The 2002-04 SARS and 2012-15 MERS epidemics, along with the 2010 H1N1 influenza outbreaks and intermittent threats of avian influenza, can all be linked to this economic phenomenon. The 2019-nCoV acute respiratory disease, or COVID-19, is part of the same trend.

What makes these known risks, with substantive historical records, 'emerging' in the current context is the nature of risk translation across globalized industries, supply chains, and economies, which is highly complex and still poorly understood. Put simply, an emerging risk is a new risk, changing risk, or novel combination of risks for which the broad impacts and costs are not yet well understood.

[18] Mansfield (2001).

In late 2011, massive floods in Thailand made seven of the country's largest industrial estates untenable, leading to supply chain shortages for more than 1,000 manufacturing firms, including clothing retailers, auto industrial factories, pharmaceutical giants, and food distribution firms.[19] The impact was compounded by the fact the floods occurred just six months after a destructive earthquake and tsunami struck the Japanese coast of Tōhoku, creating its own global economic impact. Many firms, including Acer and Honda, were forced to cut production, creating a supply deficit.

The global problem demonstrated by these localized natural disasters have only grown more complex in the years since. The wave of economic shutdowns attributed to the COVID-19 pandemic, beginning in China and moving westwards through to the United States, played havoc on technological, pharmaceutical, and industrial supply chains. It will be some time before the intricacies of the economic impact of this pandemic can be fully explored, but they will undoubtedly improve our understanding of how much is at stake from 'emerging' risk catastrophes.

Some of these risks also have the potential to be 'existential' in their nature, as examined below, and as much as known risks and emerging risks are not mutually exclusive, the same is true for existential risks — it being a reflection of the possible implications of their occurrence.

Considering Existential Risks

In addition to maintaining vigilance over an entity's risk landscape in the short, medium, and long term, there is also an imperative for us to remain aware of yet-to-emerge or growing existential risks. While climate change, biodiversity loss, and general degradation of natural capital are recognized as growing threats with ultimately existential consequences, our capability as a global society to manage these remains uncertain. Perhaps more subtle are risks of external innovations such as the endemic embedding of artificial intelligence (AI) and machine learning in production processes, making large swathes of workers redundant in the coming years; these anticipated social disruptions will have unanticipated and wide-scale societal impacts.

Future risks may involve the erosion of nuclear deterrence and the re-ignition of old geopolitical conflicts, stemming from present trade tensions or state sanctioning. Cyber risk, still emerging as a quantifiable threat for many businesses, may accelerate rapidly with the introduction of new and ubiquitous disruptive technologies, and become weaponized on a massive scale. Human health could be existentially threatened by an accident of nature, e.g., traditional pandemic, a catastrophic failure of public health characterized by an explosion of antimicrobial resistance, or a wild result of biological exploration at the intersection of genomics and AI. Many of these threats are more representative of the 'black swan' phenomena than anything seen in the risk landscape of the 21st century.

There is no widely accepted structure for considering a matrix of existential or over-the-horizon risks like these. Their occurrence may well be highly improbable and their impact sizeable, though difficult to ascertain. They demonstrate, however, the vast challenges ahead for risk professionals as the global economy sharpens its approach to risk assessment.

[19] Bland and Kwong (2011).

A Taxonomy of Macro Threats

It is now more clear than ever just how much organizations must actively explore their exposure to global threats, both known and emergent, and make bold suggestions for mitigating risks before and after disasters occur.

Before an organization can assess its exposure to risks, it must first comprehensively identify these risks. But how does one do that when faced with such a vast panorama of potential risks, merely a few of which have been highlighted above?

Capturing the scope of this risk is possible, and with ambitious and imaginative approaches, even black swan events may be mitigated. One methodology, pursued in the Cambridge Global Risk Index,[20] is to identify a suite of macro threats to the global economy, however rare and unlikely, and follow these through to their natural risk to business and business continuity. This means of organizing and visualizing global risk led to the creation in 2019 of a specific taxonomy of risks to business, in order to capture the idiosyncrasies in the global risk landscape now as they affect individual organizations. This Taxonomy of Business Risks (shown in Figure 3) provides firms with a broad entryway into considering their risk registers holistically. Once principal, emerging, and novel risks to the individual business are identified, the process of determining a risk tolerance and mitigation strategies can occur.

Figure 3. The Cambridge Taxonomy of Business Risks

Source: Centre for Risk Studies, University of Cambridge Judge Business School

[20] Cambridge Centre for Risk Studies (2018).

Global Risk Nexus

The Cambridge Taxonomy of Business Risk captures a necessarily broad range of risks. However, many of these risks are 'micro-economic' or localized, and hence would not normally be seen as posing a systemic risk. So what makes a genuinely systemic risk?

Beware the Cascades

Some of the most catastrophic shocks are initiated by one threat ,which then triggers subsequent threat events in a cascade of escalating consequences. Examples include a war provoking a sovereign crisis, or a natural catastrophe causing a power outage, which causes social unrest. So in looking to address systemic risk, it is also informative to consider why some tragedies grow and morph into genuinely systemic risks, while others don't, and are dealt with, producing more isolated implications. In short, why do some recover and others do not? Let us compare two recent examples.

There is intense fear of a cascading shock following the August 2020 industrial disaster in the Lebanese capital of Beirut. Lebanon, one of the most indebted countries in the world, is currently experiencing a severe economic crisis, in part due to its failure to implement reforms which could have unlocked access to $11 billion in international aid pledged in 2018.[21] As a result, the state has been beset by social unrest and growing unemployment since 2019. In March 2020, Lebanon defaulted on its sovereign debts, leading to a large decline in the value of the local currency and staggering hyperinflation.

The COVID-19 pandemic exacerbated this state of affairs, when the government imposed a series of mandated lockdowns shuttering almost all businesses and badly impacted the middle classes. Despite this, case numbers spiked and threatened to overwhelm hospitals.[22]

The two explosions that decimated the port area of Beirut on August 4, 2020, had a far more significant impact financially, socially, and emotionally on the region than had Lebanon occupied a position of stronger economic health and resilience. The disaster in Beirut, combined with the state's inability to repair or support the key infrastructure of the port, hospitals, local business sector, and housing for up to 300,000 people made homeless, has the potential to lead to a cascade of risks linked to social unrest, terrorism, increased interstate conflict, and disease, which again has the potential to weigh down the entire Eastern Mediterranean region.

Compare this with the fate of Iceland following the eruption of Eyjafjallajökull in 2010 which led to a steep drop in international tourism at a time of severe economic depression, currency crisis, and political unrest in the country. The volcanic eruption was not destructive to Iceland's critical national infrastructure, and, armed with strong government and policymakers, the country was able to limit the influence of the collapse of major banks and successfully reinvigorate its tourism industry by developing increased international travel links, and promoting itself as a beauty spot.[23] A decade later, it is now viewed as an economic success story among the Nordics.

[21] Hubbard (2020).
[22] Cheeseman (2020).
[23] Moore (2017).

Iceland's case demonstrates the nuanced mitigation strategy and understanding of latent market strengths necessary to transform crises into opportunities. It is unlikely that Lebanon, given its history of governmental malfeasance, sectarian tension, geopolitical location, and the level of physical damage and displacement resulting from the Beirut explosions, will be able to pursue any similar advantage from the situation. Instead there is a risk it will experience the cascading economic consequences of damage to its social and commercial infrastructure, as well as impact to its wider political and legal institutions, foreign direct investments etc.

So What Makes a Systemic Risk?

To answer this question we developed a set of criteria to aid us in distinguishing between those risks which are genuinely systemic in their primary nature, and those which while unarguably material, are more localized, either in terms of geography or in the nature of their impact. At its root is the concept that a truly systemic risk is one which can result in the breakdown of entire systems as opposed to individual parts. Of course, the connectivity brought about by globalization and increased trade and travel makes it increasingly difficult to separate local and global processes, where what happens at one level depends and impacts the other. We have tried to distinguish between risks that manifest themselves locally but could have global consequences, and those that are global and systemic in both their nature and impact.

The key criteria guiding our decisions include:

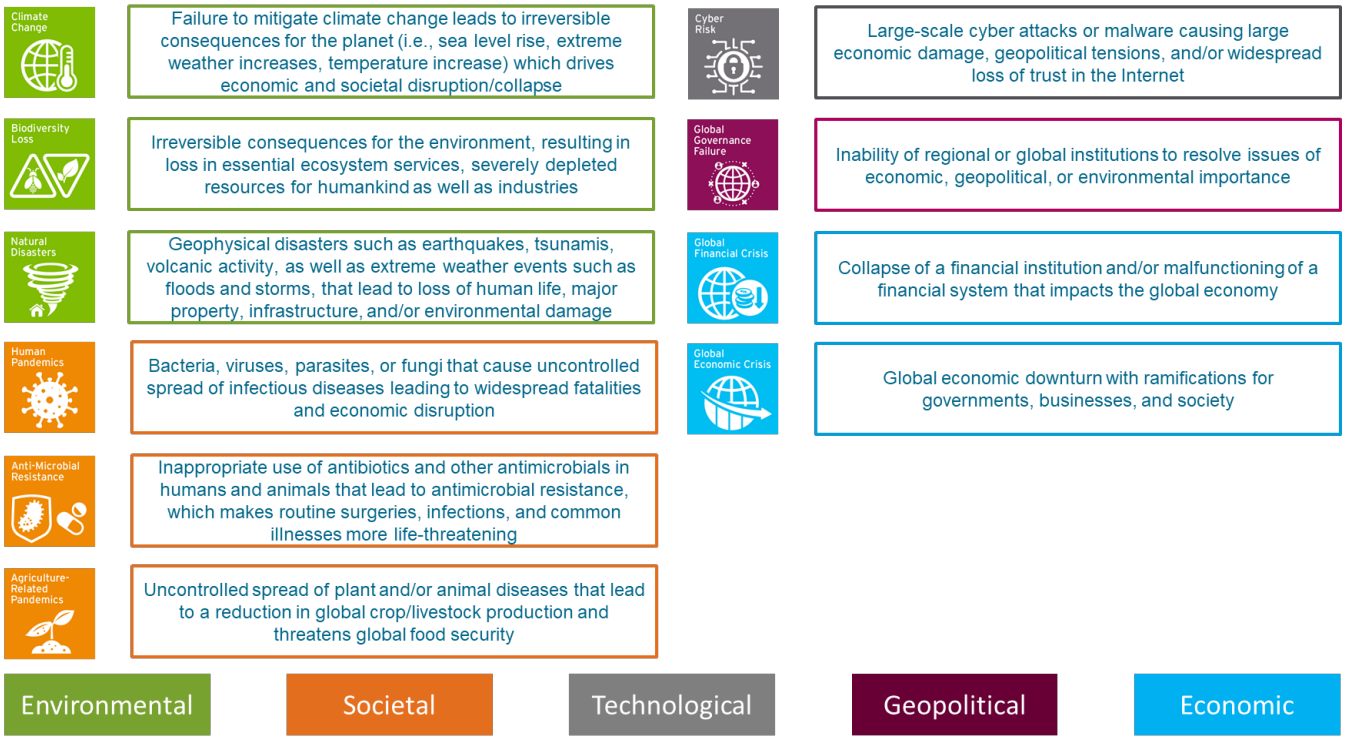
1. The risks are high likelihood and high impact with the potential to cause global economic and societal disruption (or even collapse).

2. A failure of one system can trigger or result from risk occurrence across several other systems.

3. This group of risks should be viewed collectively and as interacting systems.

We then used these criteria to decide on the 'top 10' global systemic risks to form our 'Global Risk Nexus', which span the dimensions of environment, society, politics, technology, and the economy (see Figure 4).

Figure 4. The 10 Systemic Risks of the Global Risk Nexus



Source: Citi Global Insights

We recognize our chosen risk nexus does not cover all the important global risks; two key ones notably absent are water and food crises. These are of course both vital resources we need to survive, and resource security in general is an important concern around the world. However, we think these risks are more localized, with the ability to ripple into global impacts. Taking the example of water, at the global level, there is no shortage of water, but locally there often is, depending on its availability and how it is used and processed. Climate change is expected to have an impact on the availability of water in many regions which could lead to a global water crisis, but fundamentally we are terrible at managing this precious resource, a topic covered in depth in our Citi GPS report Solutions for the Global Water Crisis.

Each of the 10 risks in the Global Risk Nexus are important, offer complex challenges in their own way, and are deserving of their own detailed deep dives, many of which we have covered in the Citi GPS Energy Darwinism report series (Energy Darwinism: The Evolution of the Energy Industry, Energy Darwinism II: Why a Low Carbon Future Doesn't Have to Cost the Earth, Energy Darwinism III: The Electrifying Path to Net Zero Carbon) plus Managing Cyber Risk with Human Intelligence. However, the scope of this report is not to cover individual risks in extensive detail but instead we try to bring out below relevant key information for each risk — such as what is it, why it is important, and where are we now?

In the following subsections, we examine why each of these risks made it into our Global Risk Nexus, under their umbrella designations of environmental, societal, economic, geopolitical, and technological risks.

Environmental Risks

For environmental risks, we consider three main threats

- Climate change,
- Natural disasters, and
- Biodiversity loss.

Between now and 2100, no prescience is required to identify climate change and biodiversity loss as two megatrends promising to impact massively on human activity, in terms of both direct impacts that accumulate over time and the response of individuals, firms, nations, and global governance.

COVID-19 has led to the postponement of key international meetings on climate (COP26) and biodiversity (COP15), but we should not lose focus on these two global issues, which are also deeply inter-linked. Climate change is one of the greatest challenges of our times, the impacts of which affect every country, are far-reaching, and are potentially catastrophic. Before COVID-19, the world was on a trajectory to a global temperature rise of 3.2°C, resulting in warming oceans, shrinking ice sheets, increasing sea levels, and increases in the intensity and frequency of extreme weather events — all of which having negative impacts on the global economy and society. According to the Intergovernmental Panel on Climate Change (IPCC), if we want to give ourselves a reasonable chance of limiting climate change to the 1.5°C limit, we have to significantly reduce emissions by 2030, and bring them to net zero by 2050. The UN Environmental Programme (UNEP) estimates that in order to meet these targets, we need to cut global emissions by 7.6 percent every year for the next decade.

While COVID-19 has been a global tragedy, it has provided a brief respite in the inexorable rise of emissions and pollution, and has led to widespread calls to 'build back better' (and greener) and perhaps a more broadly held belief that tackling climate change is in fact possible. According to the International Energy Agency (IEA), mobility, which is typically responsible for 57 percent of global oil demand, declined in the early months of 2020 at an unprecedented rate, with regions in lockdown seeing reductions in road transport of between 50 and 75 percent. Global average road transport levels fell to half of their 2019 levels. The latest data show that primary energy demand decreased almost 4 percent in 2020, with global energy-related CO_2 emissions falling by 5.8 percent, which equates to an absolute decrease of ~2 billion tonnes of CO_2.[24] Putting this in context, this reduction is the largest percentage decline in the last 70 years, far greater than the 1.3 percent fall in 2009 driven by the Global Financial Crisis.[25] Decreasing CO_2 emissions from the transport sector alone accounted for more than 50 percent of the total global decline in CO_2 emissions in 2020.[26] However, it is worth noting that the recovery of road transport activity in emerging economies in the second half of 2020 was a key driver of a rebound in emissions. The real silver lining though is that within electricity demand, renewables, given their zero cost marginal nature, actually saw demand rise, partly due to new capacity. This means conventional generation, in particular coal, was impacted more than the overall drop in electricity demand.

[24] International Energy Agency (2021).
[25] Carbon Brief (2020).
[26] International Energy Agency (2021).

The share of renewables in global electricity generation saw the largest annual increase on record, from 27 percent in 2019 to 29 percent in 2020.[27] Certainly the resilience of renewables and the amplified impact on conventional energy to any reduction in demand provides further food for thought in terms of future capital expenditure being devoted to conventional energy.

We conduct a scenario analysis and stress testing later in this report, highlighting examples directly related to climate change, but in short climate change offers two key impacts, as outlined by the Task Force on Climate-related Financial Disclosures (TCFD): transition risk (i.e. the extent to which a company or economy may have to adapt its operations or strategy to a low carbon future) and physical risk. Physical risk is in some ways easier to model, with the obvious manifestations of climate change likely to be rising temperatures, with potentially devastating impact on agriculture and food and water shortages, raising a terrifying specter of mass climate-driven migration. The list goes on, with rising sea levels (particularly important with many leading global cities located in low-lying coastal areas), more frequent occurrences of extreme weather such as storms and hurricanes, and severe disruption to precipitation levels and potential flooding, as well as heatwaves in cities, pollution, and other impacts on health.

We have classified Natural Disasters as a threat of its own within our top 10 global risks, but it is closely connected with climate change. Natural disasters have increased since the 1960s, rising 35 percent since the 1990s and becoming more severe.[28] While we cannot attribute extreme events to climate change with absolute certainty, an emerging scientific field called 'extreme event attribution' is making it possible to assess how human-induced climate change is connected to extreme weather events. Scientists have recently found the 2019 European heatwaves, which set all-time high temperature records across several countries, and the Australian bushfires in 2019-20 were made more likely and intense as a result of climate change.[29] Effects of climate change could also be far more widespread than just weather patterns via the impacts of, for example, ocean acidification (through the absorption of CO_2) which could have dramatic impacts on sea life and hence food chains, leading us neatly into biodiversity loss.

The global issue of biodiversity loss is just as significant as climate change, and awareness is growing rapidly beyond conservation experts. Biodiversity is critically important in providing the essential goods and services we need to survive such as food, clean air and water, medicine, and shelter. It also plays an important role in regulating the climate.

Studies indicate $44 trillion of global GDP is dependent on nature,[30] and the costs of inaction on biodiversity loss are extremely high — between 1997 and 2011, an estimated $10-$31 trillion per year was lost in ecosystem services due to land-cover change and land degradation.[31] We are losing biodiversity at staggering rates, and have already caused the loss of 83 percent of all wild animals and half of all plants. The UN reports around 1 million species are now threatened with extinction, and the current global response is not sufficient.[32]

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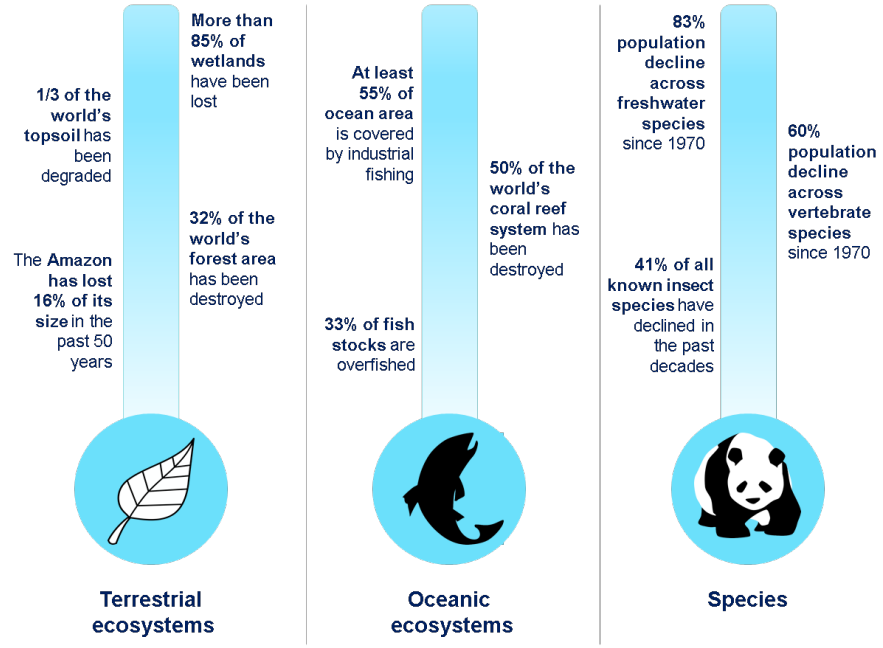
[27] Ibid.
[28] International Federation of Red Cross and Red Crescent Societies (IFRC) (2020).
[29] van Oldenborgh et al. (2020).
[30] World Economic Forum (WEF) (2020a).
[31] OECD (2019).
[32] Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) (2019).

Figure 5. Examples of Human Impact on the Natural World



Source: IPBES (2019) Global assessment report on biodiversity and ecosystem services

A major driver of both climate change and biodiversity loss is land-use change, for example for agriculture and commercial forestry, infrastructure development, and urbanization. Food-related emissions account for up to one-third of human caused greenhouse gas (GHG) emissions, and agriculture alone uses 50 percent of total habitable land (for a deep dive on the global food system – see Citi GPS: Feeding the Future). Habitat loss is currently the biggest driver of biodiversity loss, but climate change is projected to become the fastest growing driver.[33] Land-use change such as deforestation is also a cause of the emergence of zoonotic diseases like COVID-19.

[33] Newbold (2018).

Societal Risks

For societal risks, we consider three main threats:

- Human pandemic,
- Agriculture-related pandemics, and
- Antibiotic/ antimicrobial resistance.

Human Pandemics

While systemic risks such as climate change may take some time to make a significant impact (while not remotely ignoring the urgency of the required action), the global response to COVID-19 is rather more precipitous — an economic earthquake precipitated by a significant, continuing threat to life and health.

We are still in the midst of the COVID-19 pandemic, which has so far resulted in over 127 million cases, more than 2.8 million deaths (as of end March 2021), and at its peak 4.2 billion people in lockdown. Growing trade and travel has led to incredible global development and economic growth but it has also helped spread infectious diseases, which are emerging at an unprecedented rate. This applies to humans, animals, and plants and the transmission of infectious diseases from animals to humans (zoonosis) is on the rise. COVID-19 is a zoonotic disease, as are Ebola, SARS, and the West Nile Virus.

The advent of the first major pandemic of the 21st century will undoubtedly change the risk management landscape. Not only are the weaknesses of the world economy in the face of a modern plague now demonstrated, but there has been a socio-cultural transformation in the approach to work and travel in many advanced economies, which will have long term effects on business culture and alter long-held practices.

In addition to the more obvious changes, in the wake of the first global surge in cases of COVID-19 a wave of regulatory and compliance developments were instituted in order to accommodate and mitigate continuing risks and disruptions to the flow of commerce and support consistent economic recovery. This change in environment carries with it a host of emergent governance and compliance-based risks, which may ultimately prove systemic within a country's private business jurisdiction. Businesses may find themselves newly exposed to employee and customer health risks, avenues for internal fraud, labor, and pension disputes, governmental required disclosures etc.[34] These risks will carry their own interconnections and add to the complexity of a single firm's risk network.

Added to this is the potential for a decline or an advancement in globalization, as countries either pursue economic protectionism in light of sovereign debt crises linked to the pandemic, or seek to revive and protect supply chains and thus boost international trade. Both outcomes require a frequent re-assessment of risks in a post-COVID-19 business environment.

[34] Fancher et al. (2020).

Agriculture-Related Pandemics

Infectious disease outbreak can seriously impact the global food system, which has become highly inter-connected as more than $1 trillion of agricultural products are traded daily. Over the years, we have also lost diversity in the types of crops and livestock that we grow and rear, making them more vulnerable to pest and disease. More than 40 percent of our daily calories comes from just three staple crops — wheat, rice, and maize.[35] The Food and Agriculture Organization of the UN (FAO) estimates 20-40 percent of global crop production is currently lost annually to pests, costing the global economy around $220 billion. A major crop disease outbreak could have serious implications for global food security, and experts warn that more needs to be done quickly to prevent a crop disease pandemic.[36]

Antibiotic/Antimicrobial Resistance

The World Health Organization (WHO) calls antibiotic resistance "one of the biggest threats to global health, food security, and development today". Globally it estimates only 50 percent of antibiotics are used correctly. Antibiotic resistance and antimicrobial resistance more broadly has perhaps not had the attention it deserves, but the dangers posed by their widespread misuse in humans and agriculture are growing. Infectious diseases are becoming harder to treat, and we are becoming more susceptible to harmful bacteria during routine medical procedures. Antibiotic resistance currently kills 700,000 people every year but that number is projected to increase to 10 million by 2050 (more than any other disease), and could cause an economic crisis on par with the Great Financial Crisis.[37] Farmers will often use antibiotics in healthy animals to promote growth and prevent infection, which increases the spread of antibiotic resistance. This not only threatens human health, but also livestock production, which could see an 11 percent decline by 2050 if current trends continue.[38]

Technological Risk

For technological risks, we consider one main threat, which while single, has the potential to manifest itself in differing ways:

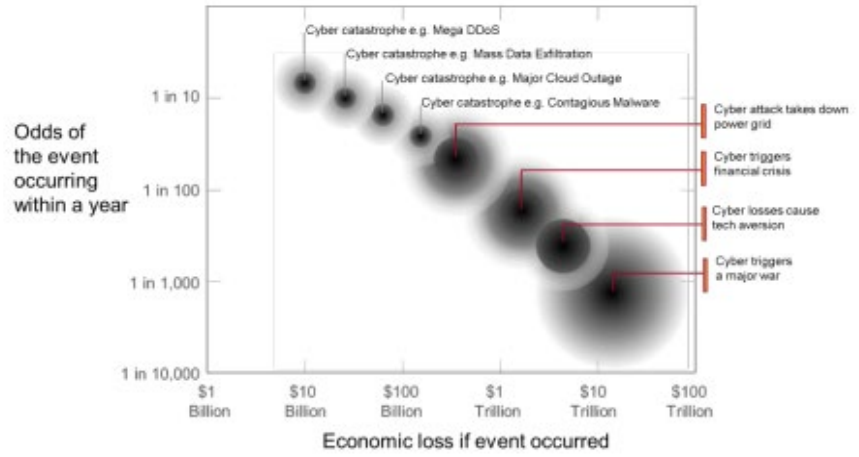
- Cyber risk.

Since the arrival of the global Internet in the 1990s, we have seen an exponential rise in digitization, which has for the most part made our lives better. Technology has allowed masses around the world to shift to remote working during the COVID-19 pandemic, and presented businesses with fresh opportunities to reach new markets and audiences while increasing the ease and efficiency of business. However, the positives of interconnectedness — access, increased speed, and efficiency — can also be used as a tool for criminal behavior, putting governments, corporations, and individuals at risk of cyberattacks. The estimated cost to the global economy from cyber losses is currently over $1.5 trillion per year, and is expected to increase as attacks worldwide grow in size, tenacity, and complexity. The global economy has not yet experienced one truly catastrophic event costing the economy hundreds of billions of dollars, but research shows attacks of this magnitude are possible and the capabilities and ambition of threat actors are growing.

[35] Food and Agriculture Organization of the United Nations (FAO) (2018).
[36] Owings (2020).
[37] World Bank (2017).
[38] Ibid.

A cyber catastrophe could send cascading impacts across multiple industries and geographies, and with growing digital integration worldwide, no industry or nation is untouched by cyber risk. Our 2019 Citi GPS report on cyber risk explores the evolving landscape in detail including tools and solutions to managing it (See Citi GPS: Managing Cyber Risk with Human Intelligence).

Figure 6. Global Cyber Risk: Likelihood of Loss Occurring from Cyber Attacks



Source: Coburn et al. (2019)

While we have not included it specifically as a systemic risk, it is also worth noting the potential of the so-called 'Fourth Industrial Revolution' to impact massively on society. While the “third” industrial revolution saw the transformation of society in response to digital technology, the so-called ‘Fourth Industrial Revolution’ refers to the ongoing process of automatization and the introduction of ‘smart’ devices in traditional manufacturing and other industries. In addition to the cyber-related risks outlined earlier, the emerging threat of the Fourth Industrial Revolution presents is own societal risks related to the loss of employment opportunities in low-skilled arenas, such as call centers, retail, and transportation, and the transformation of global attitudes to work, labor, and individual social value.

A study of more than 700 professions determined that 47 percent of total U.S. employment is at risk of being automated.[39] That percentage was higher for nations where manufacturing, agriculture, mining, and construction industries dominate. Countries with a relatively low gross domestic product per capita are more likely to be impacted, in terms of percentage of jobs replaced by automation, than high gross domestic product per capita nations. A special opportunity for the Fourth Industrial Revolution is to efficiently service a prosperous older segment of the population in the developed economies, where labor is expensive, and pensions and healthcare have deep institutional support. This demographic opportunity is driven by increased longevity, amplified by advances in disease control and a historically low global birth rate.[40] The so-called super-aging nations, where 20 percent or more of the population are over 65, included only Germany, Italy and Japan in 2014, but is expected to expand to over 30 nations including Hong Kong, Korea, the U.S., the U.K., and New Zealand by 2030.[41]

[39] Frey and Osborne (2017).
[40] UN News (2017).
[41] O'Connor (2014).

Certain modes of work, however, such as those requiring creative thinking (science, art), interpersonal trust and relationships (consultancy, social care), and responses to unpredictable demands (maintenance), are likely to thrive and thereby widen social divisions between those that have jobs and those who do not.[42] Modelling societal risks such as these for scenario analysis and stress testing is complex, and the effects of governance and public policy relating to these societal changes would also need to be considered.

Economic Risks

For economic risks, we consider two main threats:

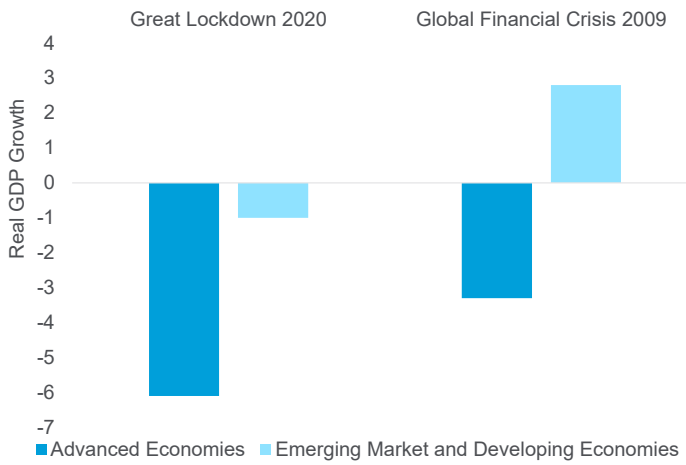
- Global Financial Crisis, and
- Global Economic Crisis.

While these might appear to be the same thing, we have distinguished between them as they represent subtly different drivers, albeit both having the ability to cause the other. In a global financial crisis, we refer to the potential of a systemically important institution (or several) or a financial market breaking down, whereas for a global economic crisis, we refer to a global downturn in the level of activity in, and the state of, the global economy.

It will be hard for most of us to forget about the last global recession, which resulted from the Great Financial Crisis. It clearly demonstrated how financial factors can contribute to economic fallout and how a financial crisis in one country can spread to the financial and real economy around the world. We are currently in another major global recession as a result of the on-going COVID-19 pandemic, and the International Monetary Fund (IMF) predicts the world economy will experience the worst global recession since the Great Depression, and one far worse than the Global Financial Crisis.[43] Global stimulus so far has reached a staggering $15 trillion, and more support will yet be needed. Despite significant progress in the development of vaccines, we still do not have a clear view of how this will end, not least due to the emergence of new variants. Moreover the pandemic has already demonstrated the implications don't stop at direct health impacts of the infection itself, with broader health implications (for example on mental health and delayed diagnosis and treatment of other conditions) as well as broader and serious economic consequences (with their own cascading health implications) when a systemic threat does take place. No country is unaffected, and for the first time since the Great Depression, both advanced economies and emerging market & developing economies were in economic recession together. During the Great Financial Crisis growth in emerging market and developing economies remained relatively strong, but the economic damage of COVID-19 is truly global, and is making developing economies more vulnerable to other crises such as poverty, hunger and conflict.

[42] Frey and Osborne (2017).
[43] Gopinath (2020).

Figure 7. Comparison of Lost GDP due to COVID-19 and GFC (YoY growth, % change)



Source: IMF

Geopolitical Risk

For geopolitical risk, we focus on one key threat, namely:

- Global governance failure.

The biggest challenges we face today are global in scale; infectious diseases and climate change know no borders, and while we are globalized in our ability to spread things, our response to them by and large is essentially still localized and uncoordinated. In some situations, more localized responses are required, such as the lockdown measures imposed by the COVID-19 pandemic, but could one argue that it was global governance failure that 'failed' to contain a local infectious disease outbreak? We now live in a world where geopolitical risks, such as a trade war between China and the U.S., and nationalist oppositions to multi-lateral organizations, are increasingly putting a strain on international cooperation. Geopolitical tensions around the world are ultimately driving a collapse in global governance which is undermining our ability to manage systemic risks. We face many global challenges ahead, some of which are genuinely existential risks, and in order to overcome them, we need effective multilateral collaboration and global structures that can deliver them.

Systemic Risk through the Lens of Inequality

It is worth noting here that we think all systemic risks should be viewed through the lens of inequality. We chose not to include it as a separate risk in its own right, because we believe it is an issue that is pervasive across all threats. There are many different types of inequality including economic, gender, ethnicity, ability, and inter-generational. COVID-19 has brought to light many inequalities, and more and more studies are coming out that find poorer people and minority ethnic groups are more likely to die from COVID-19. The UN warns the pandemic is exacerbating inequalities for women, who likely face greater economic impact. Poorer nations will suffer the most from the pandemic, and millions could be pushed into extreme poverty, which could exacerbate or trigger a host of other crises including hunger, and undermine development gains. The World Food Programme warns the pandemic could almost double the number of people suffering acute hunger, reaching more than 250 million people by end of 2020.

Many studies demonstrate the disproportionate impact other systemic risks will have on poorer nations, for example, the World Bank found poorer countries would experience larger drops in economic growth than wealthier countries as a result of antimicrobial resistance. Experts have long warned that climate change is likely to hurt poorer economies more than rich ones, and a recent study found climate change has already increased global economic inequality, resulting in a ~25 percent increase in population-weighted between-country inequality over the past 50 years.[44] The evidence is clear: poorer people and nations will bear much of the brunt of the impacts of systemic risks like pandemics and climate change, and women, ethnic minorities and people with disabilities are more vulnerable and exposed. We need to keep this cross-cutting issue pertinent across all systemic risks, and work to reduce the inequalities that harm individuals, social cohesion as well as economic growth.

[44] Diffenbaugh and Burke (2019).

Quantifying Systemic Risk

Key Metrics of Impact

Now that we have learned how to identify systemic risks, the next stage in a comprehensive risk management program would be to try to assess the scale of their impact, in order to prioritize action and allocate capital to mitigation or prevention.

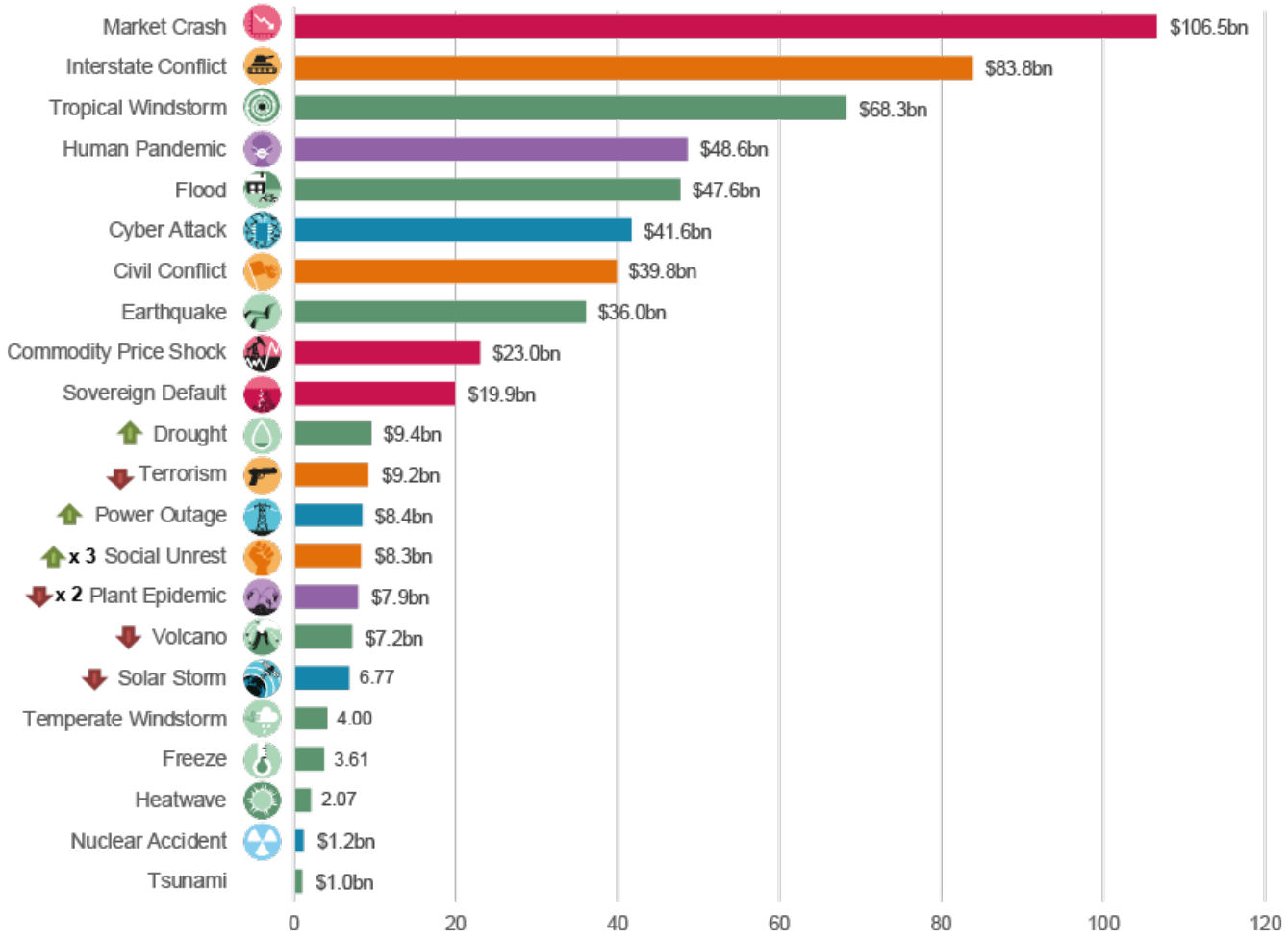
Although we still don't know what the full implications of the COVID-19 pandemic will be, it has already given us an insight into the tragic human and disastrous economic costs that can result from a systemic risk. We may be able to manage one systemic risk at a time, such as the current pandemic or the GFC, but many are on the horizon, and they are converging. If we consider the potential human lives and economic output at risk from not adequately addressing systemic risks and their connectivity, at the most extreme, one could argue everyone on the planet and global GDP is exposed or at risk. However, that doesn't help to give a relative sense of scale of the issues, or of the avoided liability if we take action.

The production of a consistent metric, or a set of key metrics, across all risks considered allows an organization to rank wildly different catastrophes, such as windstorms against wars, or volcanic eruptions against cyber ransomware attacks, in terms of their disruptive potential in order to better understand and set risk tolerance.

To illustrate this, we can use the global economic metric GDP@Risk proposed by Cambridge Centre for Risk Studies to quantify and thus compare global economic losses that are the consequences of more than 20 types of threats from the Cambridge Global Risk Index (CGRI) shown in Figure 8.

The CGRI provides a risk ranking of around 280 cities which are the economic powerhouses of the global economy and whose combined gross domestic product (GDP) make up over 40 percent of global GDP. For each city and each of the 22 specific risk types, CGRI calculates the average annualized economic loss — GDP@Risk — inflicted by that threat on that city. Shown in Figure 8, Cambridge ranks the 22 threats, each according to its total GDP@Risk across all cities in the Index.

Figure 8. Risks to the Global Economic System by Threat Type (arrows indicate change from the list compiled in 2018)



Source: Cambridge Global Risk Index

This exercise by Cambridge has demonstrated each year that it is man-made risks which pose the greatest impact to global economic integrity and that we have more control and influence over these risks than we do traditional perils and 'acts of God'.

- Market Crash is the number one threat on the CGRI. It constitutes 18 percent of the total economic loss attributed by GDP@Risk to all cities in the Index. This threat is a key representative in the broader risk class Global Financial Crisis, which is one of the 10 systemic risks in the Global Risk Nexus described earlier (see Figure 4).
- Around 20 percent of GDP@Risk for the global cities is accounted for by just two natural catastrophes — Tropical Windstorm and Flood — which are ranked number two and number five in the CGRI.
- The basket of all natural catastrophes — equivalent to Natural Disasters in the Global Risk Nexus, amount to about of 30 percent of the total GDP@Risk.
- Human Pandemic, also a systemic risk in the Global Risk Nexus, is ranked at no. 4 and contributes 8 percent to global GDP@Risk.

- Plant Epidemic — Agriculture-Related Pandemics in the Global Risk Nexus — is comparatively minor at 1 percent of GDP@Risk.
- Cyber Catastrophe, another systemic risk, captures 8 percent of GDP@Risk and is growing relatively quickly, having jumped one level from 7th to 6th place in 2019.

Sobering figures indeed. But systemic risks don't just impact cities — they impact the whole globe. Equally importantly, they don't just have an impact which can be measured in financial terms — they also have a human impact.

Another set of rankings of global disasters are shown in Figure 9 below. These events are selected from published stress test scenarios by the Cambridge Centre for Risk Studies,[45] largely constructed as notional 1-in-100 year macro-catastrophes. Conflicts and social unrest (relating to Global Governance Failure in the Global Risk Nexus), financial crises, pandemic, and commodity price shocks feature here. In these stress tests, GDP@Risk is used to measure economic loss to the global economy over a 5-year period following the crisis.

Figure 9. Ranking of Single Threat Scenario Stress Test Results for GDP@Risk

Cambridge Centre for Risk Studies' Single Threat Scenarios	GDP@Risk Range for Standard to Extreme Scenario Variants ($ Trillion Normalized to 2014)	Loss of Life	Other impacts
Geopolitical Conflict China-Japan Conflict	17 to 32	100,000 to 500,000	Due to extensive bombing, reconstruction costs are estimated at $120 to $500 billion; as much GDP is lost to the world economy as it is to the two protagonists
Asset Bubble Shock Global Property Crash	13 to 30	n/a	Large housing price shocks of 20 to 60% hit the global market causing significant investment portfolio impacts
São Paulo Virus Pandemic Scenario	7 to 23	19,000,000 to 25,000,000	A novel and highly contagious influenza virus infects over 40% of global population within a year. Though rarely fatal, the major impact of the virus is economic, due to workforce debilitation
Sovereign Default Shock Eurozone Meltdown	11 to 23	n/a	European countries default at an unprecedented rate causing currency exchange rate shocks (25% to 40%) and food price shocks of 180% to 310%
Food and Energy Price Spiral High Inflation World	5 to 11	n/a	World energy prices (210% to 440%) and food prices (180% to 310%) are shocked due to an extended period of high inflation
Cyber Catastrophe Sybil Logic Bomb	5 to 15	n/a	Companies suffer significant losses due to business interruption from the cyber attack; a general information malaise follows the event
Social Unrest Millennial Uprising	2 to 8	Some deaths and injuries	Businesses are impacted due to extreme episodes of rioting, looting, and arson. Labor shortages also occur due to people being laid off or not able to get to work due to safety
Global Trade Currency Change Dollar Deposed	2 to -2[46]	n/a	Significant impact to the U.S. government bond value (ranging from 210% to 440%) and interest rate (ranging from 180% to 310%)

Source: Cambridge Centre for Risk Studies

[45] Various reports from the Cambridge Centre for Risk Studies. Reports available from https://cambridgebusinessriskhub.com/erm/portal/publications.

[46] In the extreme X1 scenario of the Dollar Deposed, the negative GDP loss indicates that the change in currency (from the U.S. dollar to the Chinese renminbi) generated a net positive effect on world economic output.

For comparison, the Great Financial Crisis of 2007-09 drove economic losses of around $20 trillion in 2015 dollars. The figures in the table above suggest that economic losses driven by pandemics[47] and wars[48] can rival those of financial market crashes over a century. COVID-19 is already demonstrating this possibility. In Figure 4, beyond pandemics, two of the 10 systemic risks in the Global Risk Nexus are seen in financial crises, which can be as economically devastating as interstate wars, and global cyber catastrophes which appear to have a more limited impact.

Applying the Framework to the Global Risk Nexus

In order to assess the potential implications of threats within our Global Risk Nexus, we have adopted a similar approach to how we tackled the UN Sustainable Development Goals and consider impact from both a human and economic perspective. Given the difficulties in tagging risk interdependencies to specific impacts and limited literature on risk connectivity, we decided to assign a human and economic indicator to each of the 10 risks.

For our approach, we carried out an extensive literature review across the 10 risks, and chose the best available data we thought could capture the potential human and economic impact in a 'business-as-usual' scenario. An important factor that needs to be considered when assessing impact indicators is the timeframe. The impact of threats like Climate Change, Biodiversity Loss, and Antimicrobial Resistance will be felt over a long period of time, with persistent human and economic costs. Others like Financial Crisis and Human Pandemics can result in disastrous consequences, but they are relatively short-lived and are recoverable. Timing considerations make it difficult to allocate economic indicators on the same timescale across all risks, which would allow better comparison. However, we have decided to use different timescales for the indicators to try and reflect both the potential scale and duration of impact.

We recognize we are not using a consistent set of metrics, and it is a highly subjective exercise considering the many indicators that can be used for each risk. However, we have not set out to rank the risks with this approach, but to assess the scale of the issues and what is at stake if we do not act. Some will disagree with this method, but as always, we welcome feedback and discussion. We present our chosen set of indicators and their impacts in Figure 10 and we discuss some of the metrics in more detail below.

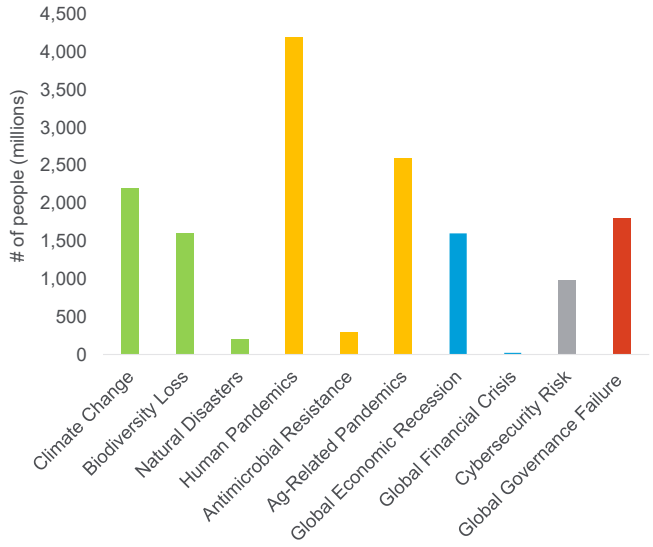
[47] Ruffle et al. (2014).
[48] Bowman et al. (2014).

Figure 10. Quantifying Systemic Risks in Human and Economic Terms

Risk	Human Indicator	Millions of People	Impact	Source	Economic Indicator	Trillions of USD	Impact	Source
	**Population exposed to deadly heat extremes**	2,200	- One of the impacts of climate change is increasing surface temperatures - Heat waves are becoming more frequent & intense and longer lasting - Number of people exposed to deadly heat extremes could potentially extend to 74% of global population by 2100 if no climate action is taken	Mora et al. (2017). Global risk of deadly heat. Nature Climate Change	**Cumulative 'lost' GDP from impacts of climate change by 2060 (2.5°C)**	44 (20-72)	- Central scenario on a discounted basis - Range of $20 (1.5°C) to $72 trillion (4.5°C) - Highest impacts forecast in South and South East Asia, Africa, and the Middle East - Only considers impact for a number of sectors such as health and agriculture; other impacts such as water stress and extreme weather events are not included	Citi GPS (2015). Energy Darwinism II
	**Number of people who depend on forests for livelihood**	1,600	- This includes 250 million of the world's extreme poor - Forests are also home to 80% of the world's terrestrial biodiversity - Forests are disappearing at an alarming rate, affecting wildlife, ecosystems, livelihoods, and climate	CBD (2018) Biodiversity for poverty reduction	**Global GDP that is highly or moderately dependent on nature**	44	- More than half of the world's total GDP - Industries that are highly dependent on nature generate ~$13 trillion, and rely either on direct extraction of resources or provision of ecosystem services - Also important to consider 'hidden' dependencies through supply chains	WEF (2020). Nature Risk Rising
	**Number of people in need of humanitarian assistance as a result of natural disasters by 2050**	200	- Compared to 108 million people today who need humanitarian assistance because of floods, storms, droughts, and wildfires - Low income people are disproportionally affected by natural disasters and risk getting caught in a vicious cycle between poverty and disaster losses	IFRC (2019) The cost of doing nothing	**Global losses from natural disasters in 2020**	0.210	- $82 billion of losses were insured - North America suffered the highest losses - Significant increase from 2019 ($166 billion) - Record hurricane season with more storms than ever before	Munich RE (2021). Natural Disaster Figures for 2020
	**Population under lockdown during COVID-19 pandemic**	4,200	- In April 2020, more than half of the world's population were in some form of lockdown in order to stop the spread of COVID-19 - As of March 2021, over 125 million people have contracted the virus and 2.7 million people have died	IEA (2020) Global Energy Review	**GDP@Risk over next 5years from COVID19**	26.8 (3.3-82.4)	- Mid-range estimate, considering a slow recovery curve with some period of economic growth before recovery process - Range of $3.3 trillion under a rapid recovery scenario to $82.4 trillion in an economic depression scenario	Cambridge Centre for Risk Studies (2020) Cambridge Business Risk Hub
	**Total number of deaths from antimicrobial resistance (AMR) by 2050**	300	- AMR currently causes at least 700,000 deaths globally per year - Alarming levels of resistance are being reported around the world, increasing the risk of disease spread, serious illness, and death - Millions of people could be pushed into extreme poverty	World Bank (2017) Drug-Resistant Infections: A Threat to Our Economic Future	**Global economic loss by 2050 due to antimicrobial resistance**	58 (30-85)	- Impacts include potential shocks to labor supply and livestock productivity (and trade), increased health costs - Greater economic impact in poorer countries - Low and high AMR-impact scenarios were also considered giving a range of $30 to $85 trillion	World Bank (2017). Drug-Resistant Infections : A Threat to Our Economic Future
	**Number of people who depend on agriculture for a living**	2,600	- Single largest employer in the world - In developing economies, agriculture accounts for ~65% of employment	FAO (2016). Increasing the Resilience of Agricultural Livelihoods	**Value of global food system**	10	- Current methods of production and consumption are not sustainable - Hidden environmental, health, and poverty costs even greater at $12 trillion	Food and Land Use Coalition (2019). Growing Better
	**Population classified as unemployed or in vulnerable employment**	1,600	- ~200 million people unemployed and ~1.4 billion people in vulnerable employment - ILO classifies vulnerable employment as own-account work and contributing family work - Vulnerable workers are often disproportionately impacted by recessions	ILO (2018/2020). World Employment and Social Outlook	**COVID-19 stimulus packages**	15	- Estimate covers the G10 group plus China, and includes increase in central bank balance sheets, government cash injections and spending, quasi-fiscal loan, and credit guarantees - Stimulus already triple that for 2008 GFC - COVID-19 has led to the deepest global recession in decades	Reuters (2020). $15 trillion and counting: global stimulus so far
	**Number of jobs lost during the 2008-09 GFC**	22	- Global financial crisis led to a global recession which resulted in millions of workers being laid off - Young people were most affected by falling labor demand	ILO (2020). COVID-19 and the world of work: Impact and policy responses	**Economic loss due to the GFC**	10	- Impacts included lost growth and subsequent recession - Write down of $2 trillion from financial institutions - Crisis spread quickly from the housing and credit markets in the U.S. to rest of the world	Chatham House (2018). The Lasting Effects of the Financial Crisis Have Yet to Be Felt
	**Number of people who experienced cybercrime in 2017**	978	- Difficult indicator to capture, we could arguably use the number of people with Internet access which is currently 4.66 billion - Almost 1 billion people in 20 countries were affected by cybercrime in 2017, with the average victim spending ~24 hours dealing with the aftermath	Norton (2018). Cyber Security Insights Report	**Annual cost of cyber breaches**	1.5	- Estimates vary on global costs of cyber crime but there is consensus that it is growing - COVID-19 has triggered an increase in cybercrime	Citi GPS (2019). Managing Cyber Risk with Human Intelligence
	**Number of people living in "Fragile states" in 2020**	1800	- This is expected to grow to 2.2 billion people by 2030 - No fragile states on track to achieve SDG2 (zero hunger), SDG 3 (good health and well-being), and SDG 5 (gender equality) - Fragility is considered across 5 dimensions – economic, environmental, political, security, and societal	OECD (2020). State of Fragility 2020	**Cost of corruption per year**	3.6	- $1 trillion in bribes, $2.6 trillion stolen - UN lists corruption as "one of the biggest impediments" to the UN SDGs - Contributes to poverty, instability, weaker institutions	UN (2018). The costs of corruption: values, economic development under assault, trillions lost, says Guterres

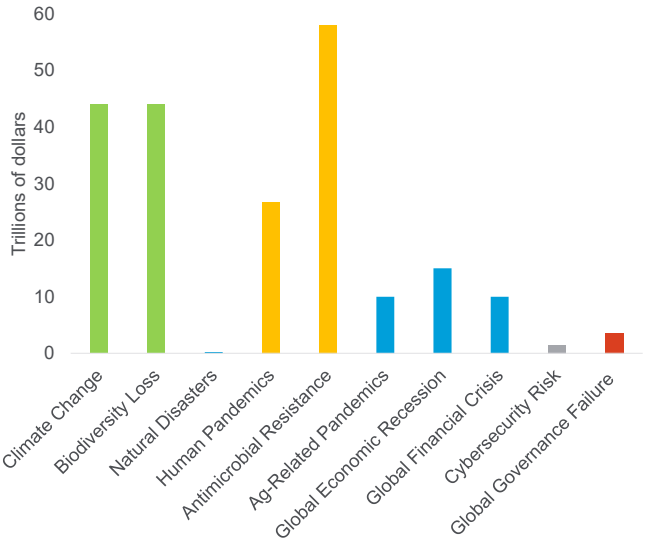
Source: Citi Global Insights

Figure 11. The Potential Human 'Costs' of Systemic Risk



Source: Citi Global Insights

Figure 12. The Potential Economic 'Costs' of Systemic Risk



Source: Citi Global Insights

For the human indicators, there were several metrics we could have used for human pandemics as we are seeing first-hand the human impact and tragic consequences it can cause — as of end March 2021, more than 127 million people have been affected by COVID-19 and over 2.8 million people have died.[49] As a result of the pandemic, extreme poverty is expected to increase for the first time in more than two decades, and the World Bank estimates that 143-163 million people could be pushed into extreme poverty in 2021.[50] This sobering estimate illustrates the knock-on effects of how one systemic risk can trigger further crises, especially in poorer nations. In the end, we decided to use the number of people who were subjected to lockdown globally which reached 4.2 billion (54 percent of the global population) in April 2020.[51] We think this indicator captures the level of disruption a human pandemic and its subsequent containment measures can bring to the world. The human indicators for the environmental risks may seem comparatively low compared to the societal risks, but the indicators (population exposed to deadly heat extremes, and population who depend on forests for livelihoods) do not capture the full extent of the threats. It is difficult to fully capture the cascading impacts of climate change and biodiversity loss, and so we have chosen indicators that allow us to estimate the number of people who are directly impacted.

Assigning economic indicators to each of the systemic risks was challenging, not only because of the timeframe component discussed above but also because of the range of studies available, uncertainties in the impact modelling, and difficulties in capturing feedback loops. For example, the IMF summarizes for climate change — "Measuring economic costs of climate change remains a work in progress, most of the potential costs lie beyond the horizon of typical economic analysis." Existing models struggle to capture extreme events or catastrophic risks like tipping points which will likely have significant economic consequences. Biodiversity loss is also a tricky one, as nature is very difficult to 'value' and there are a numerous methodologies available.

[49] The Johns Hopkins Coronavirus Resource Center.
[50] International Energy Agency (IEA) (2020).
[51] Ibid.

We decided to use an analysis by the World Economic Forum (WEF) which found that $44 trillion of global GDP is dependent on nature. However, what is potentially at stake is even greater — studies have valued ecosystem services such as flood protection, crop pollination, and carbon sequestration to be worth $125-$140 trillion per year. The indicators we have chosen for Climate Change and Biodiversity Loss are in the tens of trillions, and similar to their human indicators, should be considered as conservative estimates. If we view them in the context of the risk nexus, these two threats may be considered risk multipliers that can not only result in costly economic implications in their own right, but can amplify the potential damage across other risks. It is also worth mentioning Antimicrobial Resistance and its potential economic impact. A comprehensive analysis carried out by the World Bank modelled its potential shocks to labor supply and livestock productivity, which in turn will impact international trade. The study found annual losses could be as large as the 2008 Global Financial Crisis, but the cost impacts would be much worse given the prolonged and persistent economic damage.[52]

The numbers may not be precise, but they do give a sense of scale around the issues and the magnitude of impact if we fail to act — billions of people and trillions of dollars are at risk. More research is needed on systemic risks and their connectivity, but what we do know is that risks like Climate Change, Biodiversity Loss, Antimicrobial Resistance, and Pandemic Potential are high probability and high impact even without considering the full extent of their feedback loops. If we do cross tipping points within the risk nexus, and trigger a domino effect of systemic risks, the consequences would be catastrophic. We also know that poorer people and poorer economies are more vulnerable to systemic risks and face getting caught in a cycle of crises. We know enough to know that we need to act now.

[52] World Bank (2017).

The Global Risk Nexus: Mapping Inter-Dependencies

As we have seen in previous chapters, globalization and rapid technology shifts have changed the way we live, and while it has led to many positive outcomes such as moving hundreds of millions (if not billions) of people out of poverty, it has also inadvertently changed the nature of risk.[53]

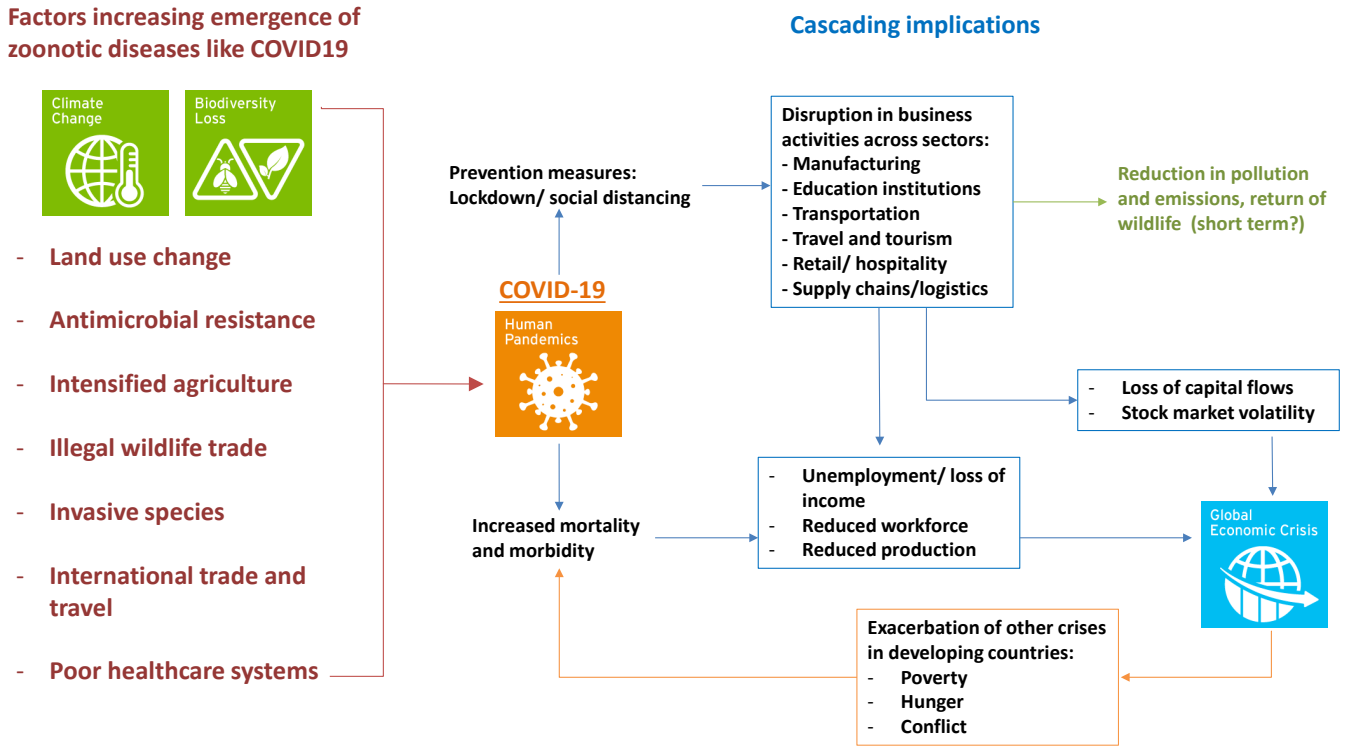
Traditionally, risk was seen as quantifiable and predictable; however systemic risks, derived from an increase in connectivity increased more interdependence with one another, have increased the complexity of global risks. Therefore, our use of traditional risk assessment, which assumes that causal links between actions and events can be known, has now become redundant in certain instances.[54] A simple example is the floods in Thailand in 2011, which caused chaos in the country and led to the deaths of more than 350 people. A secondary effect which was not foreseen was the impact the flood would have on the global computer industry, in particular the manufacturing of hard disks. Thailand is responsible for roughly a quarter of global hard drive assembly facilities, and the floods in question closed down most of the factories and manufacturing facilities, thereby affecting supply chains for hard drives and other computer parts.[55] While floods have historically been seen as a local or national issue, our reliance upon complex and interconnected systems to deliver goods and services has meant that a simple local or national issue such as a flood can easily grow to become a global issue.

The nature of risks have now changed, and it has become extremely difficult to understand, let alone quantify, the impacts that one particular event could have on society. It is important to note that systemic risks are different to traditional risks; systemic risks are global in nature, highly connected, and intertwined, leading to complex causal structures. They are usually non-linear and stochastic in their effect.[56] Global systemic risks such as Climate Change, Pandemics, Biodiversity Loss, Antimicrobial Resistance and others are also connected with one-another as described in more detail elsewhere in this report. For example, Climate Change could have a detrimental impact on Biodiversity Loss, while the loss of biological diversity could in turn lead to an increase in Pandemics.

So an important criteria of a ‘systemic risk’ is one which can trigger, or result from, risks occurring across several other systems, and moreover, genuinely systemic risks should be viewed collectively and as interacting systems. While many of these risks are not new, as the world becomes more connected, the global risks we face are growing in their interdependency and complexity, and hence the concept of systemic risk is becoming increasingly important. These risks manifest themselves across all dimensions of society, economy, nature, and climate. As an example, COVID-19 has clearly demonstrated their intersectionality when we consider both the drivers of the pandemic, and its cascading implications, as highlighted in the figure below.

[53] OECD (2003).
[54] Willcocks (2020).
[55] Kwong (2011).
[56] Lucas et al. (2018).

Figure 13. Drivers of the COVID-19 Pandemic and Cascading Implications



Source: Citi Global Insights

It is also worth noting that beyond the well-documented and obvious impacts of COVID-19, there are likely to be more subtle, longer-term implications. What might we need to prepare for in terms of resulting longer-term socio-cultural transformation, having brought inequality into much sharper focus? What are the implications for healthcare models, both in terms of availability, but also in terms of public vs. private or hybrid systems? Does mental health come increasingly to the fore? What are the generational impacts of the extraordinary disruption to education which have been witnessed? Are there resulting governance implications, on say medical research, or livestock handling, or food-chains, or indeed international travel, with vaccine passports and testing? What will our future working models look like, and what are the socio-economic implications of greater home working? Does the long-assumed juggernaut of urbanization go into reverse, and does globalization follow suit? Time will tell, but the resulting governmental inquiries, recriminations and witch-hunts are sure to be long-running, and bitter.

Accordingly, we believe that in order to better manage systemic risks, it is imperative to understand their connectivity, and take a more holistic approach to risk management. In this chapter, we aim to map out the interconnectivity of the 10 key global systemic risks identified earlier in this report into our Global Risk Nexus. We begin this chapter with a brief overview of the work which has already been done on risk connectivity, before moving to our own original analysis, adopting a similar approach to that which we used in tackling the UN Sustainable Development Goals (UN SDGs) (Citi GPS: United Nations Sustainable Development Goals) by trying to 'simplify' the complex web of risk connectivity. We group the risks into cause and effect and map out key interdependencies.

What Has Been Done So Far?

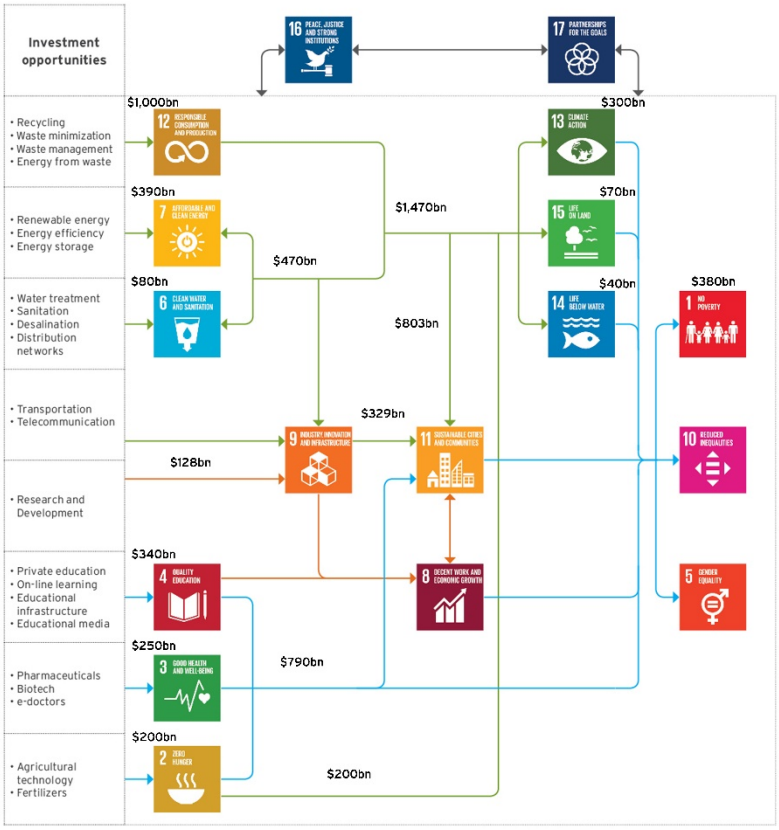
The concept of risk connectivity is not new; academics have been researching environmental risk linkages for years. The need to address unsustainable resource use collectively in what has become known as the 'water, energy and land nexus' is becoming increasingly recognized. Conservation and health experts have long recognized linkages between environmental and human health, which the COVID-19 pandemic has brought to wider attention. However, if we take a step back and consider broader risk threats across dimensions of environment, society, politics, and economics, the literature appears rather limited. The widely-recognized WEF Annual Global Risk Report considers risk interdependencies by asking respondents about pairs of global risks, and maps them out all out in one chart. Future Earth took the same approach as the WEF with their annual risk index but surveyed only the scientific community instead of a broad range of risk experts. Both sets of analyses show the importance of interconnectivity across environmental risks, and for the first time since the WEF index launched in 2006, the top five risks in terms of likelihood over the coming decade are all environmental threats (Extreme Weather, Biodiversity Loss, Climate Action Failure, Natural Disasters, and Human-Made Environmental Disasters). Future Earth also identified their own critical nexus of risks comprised of Climate Change, Extreme Weather, Biodiversity, Water Crisis and Food Crisis, and emphasized the combination of these five threats amplifies their individual impacts. In their 2017 edition, the Cambridge Global Risk Index analyzed risk connectivity using a correlation matrix across their 22 threats, which systematically assessed how one shock might cascade into another.

These analyses are helpful in showing the complex web of interdependencies across global risks and provide vital evidence for the need to address risk connectivity. However, this detailed level of risk mapping makes it challenging to come up with practical ways to manage risk interdependencies. Similar to the UN Sustainable Development Goals (UN SDGs), we believe it is the very complexity of risk connectivity itself that makes a more simplified approach necessary. Therefore, we decided to build on the existing work and focus on the key points of connectivity across the ten key global risks.

So where does one start in mapping out systemic risk connectivity? Existing risk mapping (i.e. from the WEF) illustrate the complexities and scope of the task. We soon realized this task had similar challenges to the UN SDGs, where a common complaint was that there were 17 risks, and 169 sub-indicators and all of them were interlinked and massive in their individual scale, which made the problem seem simply too large and complex to tackle. Simplistically, it was hard to know where to start.

Our approach to simplifying the UN SDGs was first to recognize that not all of the SDGs could be tackled directly — they were essentially resulting effects, while others were more genuine ‘drivers’ of other SDGs. For example, in the case of SDG13, it is hard to ‘do’ Climate Action. The way to tackle this is via SDG7, Clean and Affordable Energy (amongst of course a whole host of other measures). Similarly, one doesn’t tackle poverty directly (short of handing out vast quantities of capital) — the way to tackle poverty is via other more actionable SDG’s such as SDG2 Hunger, SDG3 Health, SDG4 Education, inequality, decent work and economic growth, infrastructure etc. Accordingly, we first broke the UN SDGs down into cause and effect, which effectively then gave us the SDGs which we could tackle directly, shown on the left of the chart below, as essentially ‘the route in’ for private capital. (Citi GPS: United Nations Sustainable Development Goals)

Figure 14. The Critical Path Approach to the UN SDGs with Annual Investment Requirement



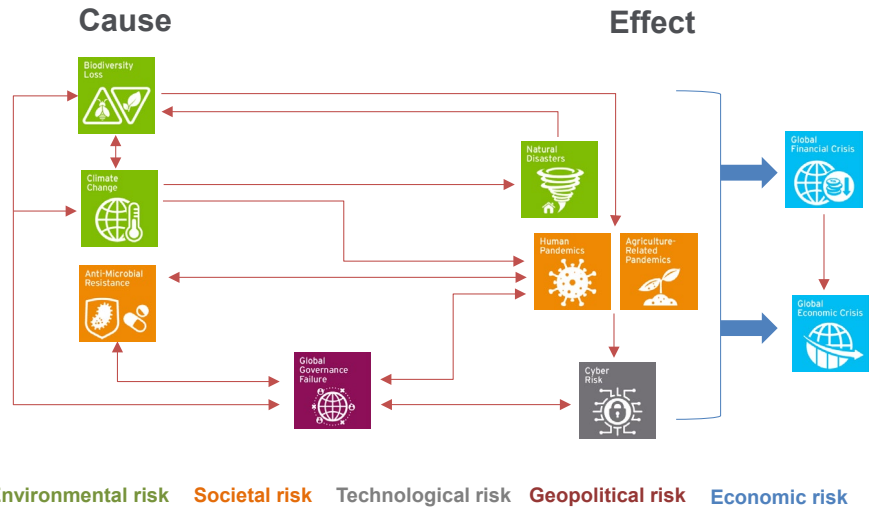
Source: Citi GPS

This simplified approach of looking at what you could action, examining the strongest linkages/influences between the UN SDGs produced the above chart, onto which we were able to overlay the financial and human opportunity of action, as shown.

Given the similarities, trying to simplify risks by breaking them down into groups similar to the 'physical/environmental' (green interconnectors), 'social' (blue), and 'economic' (red) goals above, and examining key points of connection seemed the best approach to determine a set of critical paths, which could lead to a better understanding of risk connectivity and how to effectively manage them. We acknowledge that some will disagree with this approach, arguing it is an over-simplified view of systemic risks, but we believe that as with the UN SDGs, it is only by simplifying these massive and widely interconnected systems that one can achieve the clarity of thought necessary to start tackling the problem — otherwise the challenge is simply overwhelming in its scale and complexity.

Hence our first step was to try and group the risks into 'cause' and 'effect', i.e. considering which risks are genuine 'drivers/causes' and which are more akin to 'results/effects' within the risk nexus. While it is becoming increasingly difficult to identify direct causality between actions and events, and there are many feedback loops involved, we still believe this is a useful exercise to help understand the connections across our chosen risks.

Figure 15. Risks: Cause and Effect



Source: Citi Global Insights

As an example, while it would be impossible to prove causality between COVID-19 and climate change, in principle we know that a key factor in emissions growth is land-use change, which is also having a detrimental effect on biodiversity. We also know land-use change is driving wildlife into closer contact with people, which increases the potential emergence of infectious diseases which could lead to epidemics and pandemics. Indeed while the Center for Disease Control and Prevention (CDC) notes six out of 10 already known human infectious diseases can be spread from animals, more worryingly, three out of every four new or emerging human infectious diseases come from animals.[57]

In addition to the connectivity across risk categories, we think the risks within environmental and societal risks should be considered key risk pairs — Climate Change with Biodiversity Loss, and Antimicrobial Resistance with Human, Plant, and Animal Pandemics. The connectivity within and across environmental and societal risks are indeed complex, and explored in more detail below.

Global Governance Failure is in the middle of cause and effect, as we think it can play a significant role both in triggering another system collapse as well as be a consequence when another threat occurs. In order to mitigate and manage systemic risks like Climate Change and Pandemics, we need effective global governance and institutions. This seems near impossible given today's geopolitical climate but it can be done — the Paris Agreement was a monumental achievement, and an example of what can be accomplished on a global scale when countries unite.

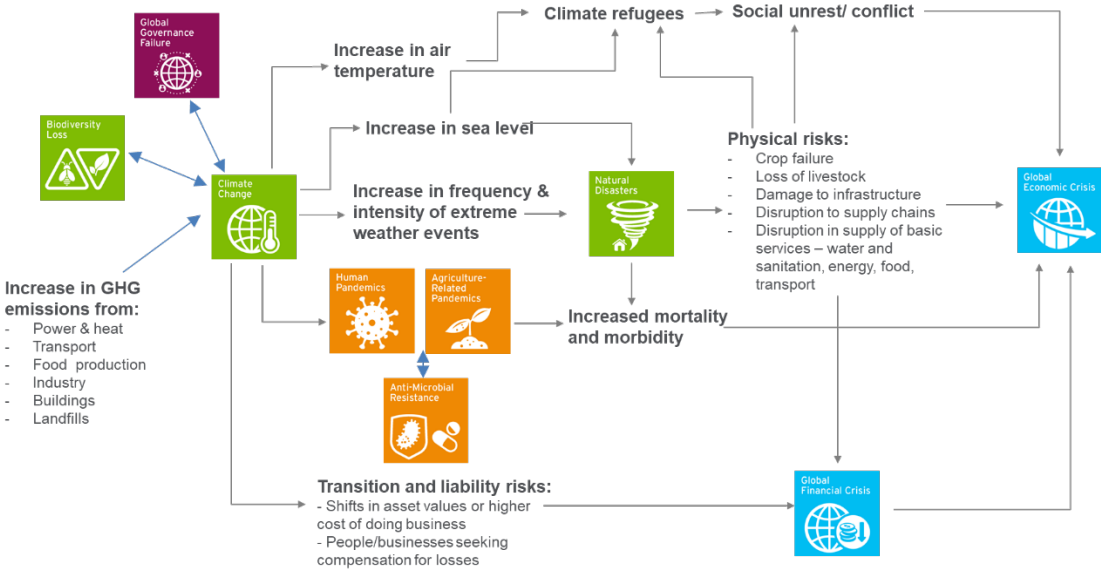
[57] Centers for Disease Control and Prevention (2017).

Cyber Risk is another threat that is arguably both a cause and an effect, but in this circumstance we consider attacks with widespread/global implications and believe it is closely connected and has feedback loops with Global Governance Failure. Other global risks can drive cyber threats. For example, there have been reports of cyber attacks targeting COVID-19 vaccine research, and the WHO has reported a five-fold increase in cyber attacks since the start of the COVID-19 pandemic.[58] A survey of cybersecurity experts found 91 percent of respondents stating an increase in remote working has led to a rise in cyber attacks.[59]

As Figure 15 above shows, we believe all environmental, societal, technological, and geopolitical risks can drive economic threats such as financial crisis and global recession, and as we publish this report, we are witnessing first-hand the economic fallout of the COVID-19 pandemic. Climate change goes hand-in-hand with increased probability of financial crisis, and both regulators and investors are increasingly recognizing and focusing on the connections between the two. Risks to financial stability include physical and transition risks, which are expected to grow and increasingly impact supply chains and business operations. A recent study analyzed how climate-related damages might impact the stability of the global banking system by modelling the cascading effects of company bankruptcies induced by climate change. It found the global banking system could be seriously challenged by firm insolvencies and that climate change increases the frequency of banking crises by 26 to 248 percent. In the study, rescuing insolvent banks caused an additional fiscal burden and an increase of public debt-to-GDP by a factor of two.[60] A number of initiatives are under way to improve information access on climate change and financial markets including the Task Force on Climate-Related Financial Disclosures (TCFD), which outlines ideal disclosures regarding climate risk. (See Citi GPS: Building a TCFD with Teeth). Figure 16 below maps out in detail how a failure to address climate change is connected to the other risks. It is not an exhaustive representation of all possible connections but helps to illustrate the cascading impacts and how it may lead to economic crisis.

[58] World Health Organization (WHO) (2020).
[59] VMware Carbon Black (2020).
[60] Lamperti, et al. (2019).

Figure 16. The Cascading Effects Between Systemic Risks



Source: Citi Global Insights

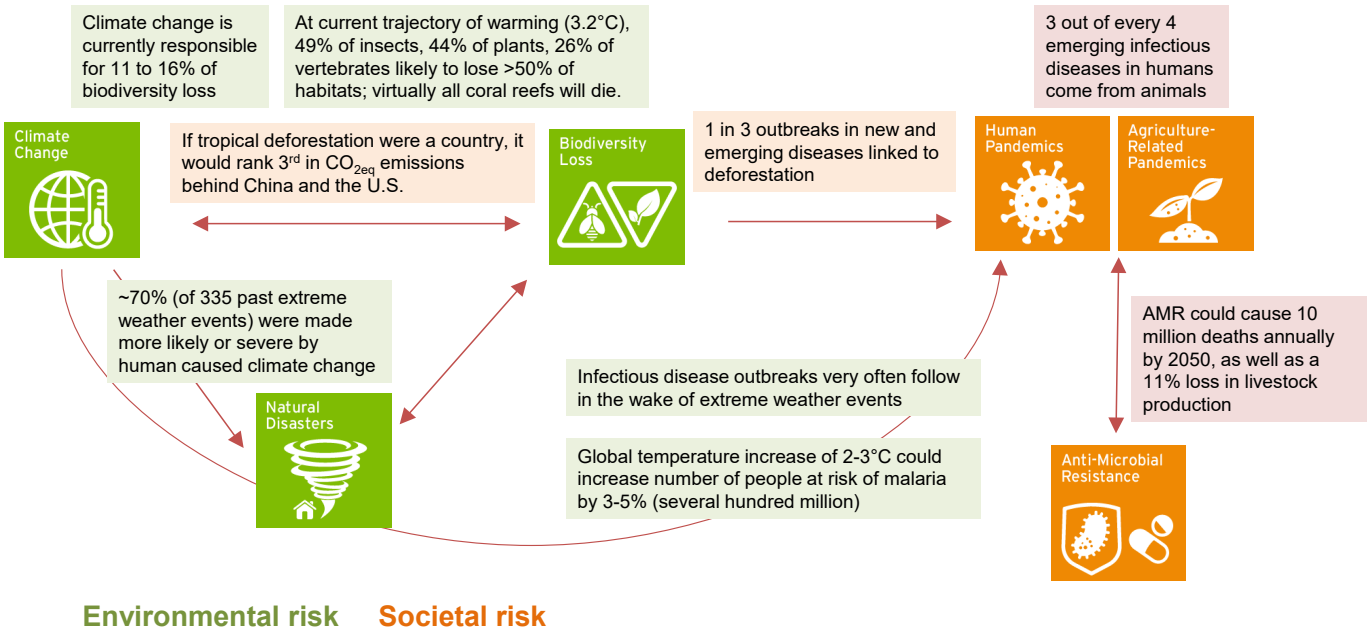
Biodiversity loss also poses significant risks to the financial sector, and an initiative is in the works for a Task Force for Nature-related Financial Disclosures, which aims to publish a reporting framework in 2021.

Interestingly, while Figure 16 shows the potential for many of the components in our Global Risk Nexus to cause economic and financial crises, it is also important to recognize the potential for feedback loops. For example, a financial crisis might lead to reduced investment in emission reduction (e.g., slowing low-carbon subsidies), or reduced investment in healthcare, though thankfully evidence so far suggests COVID-19 is actually boosting attention on 'sustainability' as a general concept; perhaps as we are finally beginning to understand the relative merits of investment in prevention rather than adaptation, as examined later in this report. Certainly economic crises could increase the likelihood of global governance failure, as individual nations look inward to minimize the damage to their own economies and steps to re-energize them – witness the parochialism seen regarding vaccine availability (and earlier with the availability of PPE), highlighting the insular response which so often results from crisis. The irony of the government responses to vaccine availability, contrasted to the global collaboration in the biotech industry (private sector) required to develop vaccines in the first place (and their provision often at cost price), is hard to miss.

Connectivity across Environmental and Societal Risks

As mentioned earlier, the connectivity across environmental and societal risks in particular is complex, but it is also an area where there has been significant prior research, including studies trying to quantify the relationships. These studies have largely focused on pairs of interactions, and we have pulled together some of the most seminal findings below to show the strong interdependencies at play both within and across environmental and societal risks.

Figure 17. The Interdependency between Environmental and Societal Risks



Source: IPBES, WRI, Carbon brief, Ecohealth Alliance, WHO, CDC, World Bank, Citi Global Insights

An important dynamic worth highlighting is the one between Climate Change and Biodiversity Loss. Climate Change is expected to become the dominant driver of Biodiversity Loss over the next few decades, but we can also expect further warming through feedback loops driven by deforestation and ecosystem collapse. Sadly, even if we manage to limit global warming to 1.5°C, there will still be consequences for the natural world; for example we would still lose >70 percent of coral reefs,[61] which will have knock-on effects for the 500 million people who depend on reefs for income and food, as well as coastal protection. There are also several ways in which Climate Change can increase the likelihood of Human and Agriculture-Related Pandemics. First, it changes and accelerates the transmission patterns of infectious diseases like malaria and zika. The WHO stresses, "Climate change is the greatest threat to global health in the 21st century". Air pollution from increased traffic and burning of fossil fuels could help viruses become airborne and more deadly. A recent study found an increase in fine particulate matter of 1 microgram per cubic meter corresponded to an 8 percent increase in COVID-19 deaths.[62] In addition, the melting of ice and permafrost could lead to the re-emergence of ancient pathogens and disease. A heatwave in 2016 melted permafrost in Siberia, exposing the corpse of a reindeer which died from anthrax in 1968. This led to 1 death, 100 people being hospitalized, and the loss of 2,300 reindeer. The threat of negative feedback loops across environmental and societal risks is very real, and we still don't fully understand all the interactions and tipping points at play. However, we know enough to recognize these risks are not separate issues; fighting global health risks is ultimately also about tackling Climate Change and Biodiversity Loss.

[61] Intergovernmental Panel on Climate Change (IPCC) (2018).
[62] Wu et al. (2020).

While much of this chapter has focused on environmental risks such as Climate Change and Biodiversity Loss, this is more a reflection of the current focus on environmental risks within both the public and private sector, as well as in society more generally, rather than any deliberate comment about relative importance. The other risks bear equal scrutiny when it comes to scenario analysis and stress testing, not least as their effects may be witnessed far sooner and more quickly. For example, if retreating globalization and rising trade wars lead to increasing international tensions, a catastrophic cyber attack is all too plausible. At the extreme, imagine a world where computers ceased to work overnight. Along with everything else dependent on them, a rapid reversion to the dark ages could quickly ensue with the potential of a breakdown in the structure of society up to and including anarchy. Antimicrobial Resistance could produce results which would significantly eclipse today's COVID-19 medical emergency. An Agricultural-Related Pandemic which wiped out one of the three crops providing 60 percent of all the plant-based calories which humans consume around the world, would have effects that could again be genuinely catastrophic. These risks could manifest themselves far more quickly than Climate Change or Biodiversity Loss — remembering of course that although long-dated, the latter two have the potential to be truly ‘existential’ in their nature.

Section 2: Prevention, Mitigation, and Adaptation

Prevention, Mitigation, and Adaptation

“Since the financial crisis of 2008, the world has been drifting towards a perfect storm of financial, political, socioeconomic, and environmental risks” *Nouriel Roubini*

Scientists have been warning us for years about pandemics and that it is not a question of 'if' but 'when'. Addressing the immediate health crisis should of course be a priority, but we also have been presented with a rare opportunity to reset and rebuild a more sustainable, inclusive, and resilient future. We cannot return to a business-as-usual path that was heading towards a 'perfect storm' of systemic risks with potentially catastrophic consequences.

The COVID-19 pandemic has brought to light three important trends:

1) The inter-connectivity across planetary, human, and economic health;

2) How crises disproportionally affects the poorest people and nations; and

3) Just how unprepared the world is when a global crisis takes place.

Having identified our Global Risk Nexus of 10 key systemic risks, quantified their potential impact in human and economic terms, and tried to understand their interlinked nature, how do we adddress those risks — in terms of preventing them, or where that is not possible, limiting their impact, or preparing ourselves as best we can to live with them?

As a starting point, we interview two experts in the field of systemic risk to hear their views on the barriers to addressing systemic risk, and actions to overcome those obstacles. Our first expert is Dame Inga Beale, previously CEO of Lloyds of London, and President and Chair of the Chartered Insurance Institute, who brings enormous insight from the world of insurance, which is, given the core function of insurance, considerably ahead of the broader financial community in quantifying, mitigating, and mutualizing risk. Our second expert, Mark Carney, ex-Governor of the Bank of England and Chair of the Financial Stability Board and now UN Special Envoy on Climate Action & Finance, is arguably the individual who has done most to drive awareness of the implications of climate change for the financial sector, from the seminal ‘tragedy of the horizon' speech, to being one of the two founders of the TCFD via the Financial Stability Board.

Their views on the barriers to addressing systemic risk form a critical element of the proposed solutions for mitigation and prevention which follow the interviews.

An Interview with Dame Inga Beale

Dame Inga Beale is an experienced business leader having spent over 38 years in the insurance sector. From 2014 to 2018 her final executive role was as CEO of Lloyd's of London. She now has a portfolio of non-executive roles as Chair of Mediclinic International plc, as well as an independent board member of Crawford & Company, and London First, and a member of the London Mayor's Business Advisory Board.

During her 5 year tenure at the 330-year-old financial institution of Lloyd's, Dame Inga was responsible for accelerating the modernisation of the insurance market, embedding an innovation culture, and expanding the market's global access across new, high-growth markets including China, Dubai, and India. As the first female Chief Executive of Lloyd's, she also played a critical role in advancing diversity and inclusion initiatives across the global insurance sector.

Dame Inga started her career in London in 1982, qualified as an Associate of the Chartered Insurance Institute in 1987 and is now a Chartered Insurer. She was awarded her Damehood in 2017 for services to the U.K. economy.

Jason Channell: *What are some of the barriers to dealing with systemic risk, and why are we so bad at managing it?*

Dame Inga Beale: We've done a lot of this analysis and we've identified all these risks, such as in the WEF report, looking at how risks change year-on-year. However, it seems crazy that we do this assessment, and actually put numbers to some of these risks, and yet we don't do anything about it. As an example, Lloyds did a piece of work with Cambridge which was looking at risks for cities — a particularly important topic given urbanization trends. There were some shockingly large numbers which came out of that analysis, but when we actually tried to engage with city governments to try and get them to be proactive, we had very limited success or interest, with the exception of New York, some Australian cities, and Bristol in the U.K. But cities such as London, and governments in general, had little interest. So fundamentally, nothing happens. I think one of the issues is that business does a lot of this work, much of which is admittedly government sponsored. But because governments are so short term in their nature, we found it very, very difficult to get traction and then continuity year-on-year, because a lot of this work takes a long time. I don't know how we combat that other than with initiatives such as the Chapter Zero initiative in the U.K. for FTSE Directors. Business has got to just do this and get on with it because it's hard to work with governments because they keep changing; the people responsible keep changing, they have short term priorities, and are often focused on votes. So they're not necessarily making the right decisions all the time for the economy or for whatever these risks are that are coming.

Jason Channell: *This sounds reminiscent of the UN SDGs, which were put in place for countries around the world, but it's very much the private sector which has embraced them, and is having arguably significantly more impact than most governments around the world. Similarly, electoral cycles can prove a barrier to investment in the UN SDGs given their long-term nature, and the long lead times between investment and reaping the benefits of that investment. So if we need to be more reliant on insurance and the private sector, what measures might we put in place to encourage that shift?*

Dame Inga Beale: There's a piece of work in the insurance sector that was launched a few years ago called the Insurance Development Forum, which is aimed at governments in countries where people don't really buy insurance. In these countries no one really buys insurance and therefore if a disaster hits — it could be an earthquake, a typhoon, anything — there is basically nothing to pay for it. Conversely, if you have widespread insurance the money floods in from other countries and supports it. The Insurance Development Forum (IDF) is working with governments, I think it's identified six or seven countries now, such as the Philippines, and a few other economies very susceptible to natural catastrophe, and they're trying to come up with a shared risk mechanism. In fact there was a Caribbean risk pool that came together for some of the poorer Caribbean countries, which I think is actually still running. Based on that there was an African insurance pool that came up for some of the African countries. The Insurance Development Forum is trying to go beyond that to other countries.

Jason Channell: *This concept of the 'protection gap' is gaining traction more broadly, as evidenced in a recent report by the Cambridge Centre for Risk studies "Optimising Disaster Recovery: The role of insurance capital in improving economic resilience") This report tries to identify the characteristics of a good recovery, and why it is that some nations recover better than others, looking at a number of detailed case studies to draw some conclusions. One of the key statistics to emerge is that for every extra percentage point of insurance penetration, disaster recovery speeds up by about a year. On top of that relationship, there are other characteristics that are very idiosyncratic to different regions that can either accelerate or decelerate the recovery. For example, for a natural disaster, the empirics show that authoritarian regimes are particularly well equipped to manage them, in terms of recovery time. Conversely, the benefits of a more 'libertarian regime' may not be in the administration of disaster recovery, but might instead be in the management of capital. So, while a more open democratic structure may have better governance, and may be better placed to encourage capital standards, regulation, and therefore insurance, it may be less effective at the action of recovery, other than the ensuring availability of capital. A typical example would be a Hurricane Katrina, or the flooding along the Mississippi, where being in a highly-capitalized environment generally doesn't always translate to locale*.

Dame Inga Beale: The work we did at Lloyds showed that for every 1 percent additional spent on insurance, there was a 2 percent benefit to the economy, because the capital rolls on and then gets reinvested. We need to get governments to understand that there's sort of a double benefit to insurance. I often used to talk about the governments in mature markets effectively being the competitor of the insurance/reinsurance sector, and this is particularly true in the U.S. Because, as the decades go on, each one of these natural disasters is more and more covered by the government. Given the political implications, governments are inclined to bail out people without insurance, and therefore people don't bother buying insurance. So, the insurance contribution to these natural disasters has gone down each decade in the last five decades — it's quite extraordinary that governments are therefore taking on more and more of this risk themselves.

Jason Channell: *This is a fascinating dynamic. So, if the inclusion and pricing of systemic risk is going to become important, do we expect this trend to continue, where people will expect a government to bail them out at an individual level, but potentially not at a corporate level?*

Dame Inga Beale: Well, I'm afraid that we are seeing it right now, as we've seen it in the U.K. with flood risk. I've worked in the insurance sector for 38 years, but I'm now looking in on it from the outside, it's not something I feel proud about. Every time things start getting really tough, the insurance industry tends to pull out, which is what happened in flood prone areas in the U.K., hence now there's a government backstop, so there's a pool. The same thing happened for terrorism back in the '90s when there were terrorist attacks in London. It was only meant to be a temporary thing, but of course, what's happened is it's stayed there, and now there's a pool of money sitting there and nobody knows quite what to do with it, but its retained as there might be a massive terrorist attack. The same is now happening with flood risk in the U.K. Many other countries have taken it upon themselves to provide certain government-funded pools for various risks, including a whole debate around cyber exposure, which is of course one rising risk that we've been talking about a lot. There were many debates with insurance CEOs having different differing views as to whether the insurance sector was able to take this risk on a pool, or whether it should just be paid for by the government. I feel quite strongly that if insurers keep dipping out of the tough risks they will become irrelevant.

Some years ago we did another analysis of all the risk managers of all the corporates, and insurers are covering less than 5 to 9 percent of the risks that corporates face now, which just isn't good enough. It's not necessarily so for individuals, but for businesses the risks have moved on and the insurance sector hasn't really kept up, and keeps shying away. Now, some of it is around concern about getting the pricing wrong, so it's an unknown risk. It takes you a while to get the statistics, but there's been billions spent on modelling and scenario building, but at the same time, a lot of the issue is also capital. In the U.K. the FCA (Financial Conduct Authority) recently took some of the insurers to court, which is unheard of, for not paying business interruption for the COVID-19 pandemic. The insurers were saying, "There's not enough capital; we don't have collectively enough capital to pay for this". I think that's when you start to look at the capital swirling around the insurance sector, and realize it's not very large compared with what's at the banks, and even a lot of the big massive global corporations now. There's an imbalance there and I think there's got to be another solution going forward for handling these mega systemic risks.

Jason Channell: *In the U.K. the argument for setting up Pool Re (basically the underwriter/ insurer for terrorism risk) was that unless there had been a government backstop, initially there wouldn't have been participation by the insurance industry or by corporates, because you could either not trust your policy would amount to anything or you were on the hook for too big a risk. But it is possible to imagine a scenario where different elements of this mechanism, or different tranches, get handled by different market participants corresponding to the economic value that the insurance offers and the protection they get, and where that relates to the size of the business.*

There is however a bit of a problem with this, in that if you accumulate vast amounts of capital, how is it going to be usefully used? So Pool Re might, for example, have in its coffers 60 or 80 percent of what it believes it would actually need if a large attack was to happen, which means the government would effectively be off the hook. However, that's not to say that Pool Re would necessarily be investing it wisely, because is it being invested back into reduction of exposure to terrorism?

Similarly, looking at Pan Re (pandemic reinsurance), which organization is going to have enough capital to even think about covering pandemic insurance? There has to be a government backstop to get it started. So a follow up question is if Pool Re. is partly successful and partly not, where is the right balance, between government backstops and insurance from the private sector?

Dame Inga Beale: Yes, well of course. I had a discussion with Pool Re a few weeks ago about Pandemic Re (Pan Re), because, again, I just feel that the insurance sector, the private sector, should not shy away from taking this on. Of course, what happens is that there is a challenge between the need to make profits and serving their core purpose of the provision of insurance. Lloyds for instance became the leading insurer of cyber, and I used to debate publicly with key market participants who changed their tune actually after a while about the fact that we should take that risk on in a controlled way. You can try and assess the risk, and you have limitations, so you can actually do some sort of aggregation across the world, because cyber risk knows no geographic boundaries. That was our approach, trying to identify the exposure, doing scenarios, numerous scenarios actually — I think we landed on something like eight different scenarios for a massive cyberattack across the world. Then we would make sure that we aggregated it and limited the coverage we gave.

That was how we approached cyber and I think the pandemic should be handled in the same way — there could be an industry approach, which could be very sensible so that you get the best brains together to do the modelling, and you understand how scenarios work and what interacts with what, and how they intersect. Then, risk would be spread amongst the private sector, and that would be my preference, but I think that Pan Re is going down a different route.

Jason Channell: *Which brings us neatly on to a key issue in this report in terms of the increasing connectivity of systemic risks. So how is the insurance industry addressing this increasing connectivity?*

Dame Inga Beale: It depends. So if I think back to the financial crisis, we really hadn't done any connectivity across the world because the way insurers tended to run things, we were very much used to physical risks and physical assessment, and that always had a geographic boundary. It might have been a European storm but it had some sort of limits. So when it came to the financial crisis we hadn't really added up all the exposures. Fortunately the insurers didn't do too badly out of it at the end of the day, but we did a fairly poor job, so we've been trying to, over the years, do more assessment of these risks. We call them the casualty space, so any liability element where it's not necessarily physical damage. We have tried to do this but I would say, it's still not necessarily a strong point. Again, I think, it's because companies then limit their policies, reduce the actual amount of cover that people can buy in terms of insurance, aggregate it, put probable maximum loss scenarios on it, and then put that against the capital and say that's what we feel comfortable with. So, it's relatively crude compared with say modelling Florida windstorms, which have been going on for decades and, I think, that's so much more sophisticated. Whereas we're not really very good at anything that's not very tangible. We've made attempts for instance, looking at one of the cloud providers going down, because there are very few cloud providers in the world. What would happen if one of them went down and they controlled 30 percent of all cloud traffic? We've done scenarios like that. But generally for all the types of systemic risks, I would say it's pretty unscientific at the moment. It's not as far advanced as it should be for the insurers.

Jason Channell: *So it appears in terms of policies we're still struggling with dealing with one systemic risk, let alone trying to look at the domino effect — for example if we have a drought in one country which leads to famine, which leads to a pandemic etc. or, we have climate change again being the big one, which again leads to drought and migration….*

Dame Beale: The thing is again the way insurers tend to handle this. For instance when we had the earthquake and typhoon in Japan, it then rocked across the whole world. So you've got all the supply chains being broken everywhere. Of course what insurers do then is they have sub limits on people's policies for supply chain risks and things like that, and that's the way that they choose to do it. It makes insurance policies sometimes for big corporates quite complicated, lots of terms, conditions, exclusions, with different categories of limits for the reason that otherwise you cannot control your exposure to an overall catastrophe. The physical piece in location is fine — it's all the ripple effect across the world.

Jason Channell: *Which raises another interesting question. Insurance markets are fundamentally about pricing risk correctly and spreading that risk across the system. What successes and failures have there been in the insurance markets regarding systemic risks and what lessons can financial markets — i.e. investors, corporates and sovereigns — learn from that long standing experience?*

Dame Inga Beale: Well, one of the earlier issues that happened which nearly broke the entire Lloyds market was asbestos. That was because of the long tail nature of it, they did not understand why or how long it would take to discover resulting medical problems in people, and that nearly crippled the entire market. The other reason that it nearly broke, was because people kept reinsuring themselves, laying the risk off, so it went round and round like a spiral — in fact it was actually called 'the spiral'. So the quantum got so huge, and these notifications that you were liable came in 20 years later — it really was a disaster. What stopped in the insurance sector was this continuous offloading of risk. There was suddenly a limit on how many times you could pass the risk. There are obvious parallels here with the financial markets. That was a big, big change which had a dramatic impact and really started getting people to think about how the policies should be structured. So nowadays, the long tail nature of when the claims are actually made is better understood. For instance, doctors now are struggling to get insurance which used to be done on a different basis. Previously, say you bought your insurance and you did an operation in 2015, but you didn't have a claim coming until 5 years later, you would go back to that 2015 policy. The policies tend to change now, so you need to have the policy in force in the year that the claim is actually made. It's making it easier for certain insurers to price risk, but it means that if you're a doctor and you retire, you have to keep buying insurance for as long as you are alive, and so it's got some real negatives to it for the policyholder. This is true also for corporations and companies that buy insurance, because the claims can come back to bite you down the track — if it's a claims made policy it's not great for the policyholder, but the insurers love it. So they've again put another limitation on to stop the asbestos issues coming back.

But you've also asked about successes. Well, when it comes to natural catastrophes, a Florida wind or something like that, we are much better at pricing that now. So while there were some horrible numbers coming through about Hurricane Laura for example, there's hardly ever one event which is too significant. Fundamentally, when we did some analysis a couple of years ago with the Bank of England, it was all about solvency. We said, there's not likely to be a single natural catastrophe not that's likely to cause any big issues for the insurance market anymore, because we've got our pricing right. But that is really because the modelling is so sophisticated now, and we've spent billions as an industry on understanding these models and building scenarios and tools.

Jason Channell: *Which highlights an interesting distinction between essentially a single event and a systemic risk. Is it broadly correct to say the industry is in a sense shying away from the massive systemic risks because they're too big to handle, and hence they're putting limitations on liability and exposure, whereas for something which it can statistically quantify, the industry is very happy to cover it, because that's what it does?*

Dame Inga Beale: Yes, that's right. I mean, it's a simple way of saying it, but if we spend as much on some of these systemic risks as we have done on Florida windstorms or hurricanes, we might be in a very different place. But for some reason that's where we've chosen to spend the money.

Jason Channell: *Is it because the liability side of the systemic risk equation will be so big that even if it was to be priced correctly, even with a relatively low probability which may or may not be correct, the premium is going to be so high that policyholders just wouldn't go for it?*

Dame Inga Beale: It could be, and as I said previously, there could perhaps not be enough capital in the insurance market, and there aren't necessarily the mechanisms to offer the risk. So as far as I know, and my figures might be getting out of date, but in say Japan — a mature insurance market — we will probably find for a big catastrophe that only 30 percent of it is actually insured, because there's not enough capital in the insurance and reinsurance sector to take the risk on.

Jason Channell: *So is it partly chicken and egg in that, if the liabilities were bigger the premiums essentially would be bigger, which would put more capital into the industry, which theoretically could play out over time?*

Dame Inga Beale: It could, but it's because a claim would be such a peak, and fundamentally we don't have the sophisticated modelling around some of these other systemic, more intangible risks at the moment. The big peaks for everyone in insurance is a California earthquake, a Florida wind event and a Japanese earthquake — and a Japanese earthquake is fundamentally only 30 percent insured, while Florida wind is now about 30 to 40 percent insured. They balance each other out as the peak risk, whereas if they go up any higher they shoot up above everything else, and as I said, there's not enough diversification for the amount of capital that's in the system. Whereas if you have more insurance penetration in other countries that currently don't buy much insurance you've got a better spread of risk, which is what the IDF insurance development forum is all about — if we get more money in the system, you can take on these higher exposures because you get better diversification.

Jason Channell: *So it seems there are several elements here, including the 'modelability' of a risk, regulation, access to capital and capital markets, as well as the mechanisms by which the capital can be packaged into a product, with the right market participant, whether it's a business, an individual, or a city or government, actually able to buy policies or Cat (Catastrophe) bonds, or whatever the appropriate vehicle is. For some events, because they're a recognizable and understood shock in a specific geographical area, we can get our head around them, the mechanisms for buying and protecting are very clear, and why you do it is clear — and it turns out you can afford it, because your house is worth so much that it's worth putting in a floodwall. But if we are looking at a systemic risk, which can ripple out both geographically and over time, the mechanism for charging or recovering the financing becomes much more complicated. Which raises the question of whether it is as much a mechanism problem — who's the beneficiary, who can afford it? This brings us back to the earlier points about breaking risk and cover down into 'chunks'. If you're unable to chunk some of these risks, you can never build enough layers to cover the risk, you can never get the capital involved, and you can never arrange pay-outs.*

Dame Inga Beale: One other thing that has changed is accounting rules. The big reinsurers in Europe used to be able to reserve for future claims, so when you collected all your premiums for say a Florida wind, you would store that money up, year after year, and the pool would get bigger and bigger, and you weren't paying tax on profits — it was a reserve that you were allowed. Then, accounting regulations all changed, and suddenly you had to release those reserves every quarter if they haven't been used according to your modelling, which completely changed the dynamics of how much money is swirling around the insurance industry. It's a very interesting subject, particularly in the U.S. with U.S. GAAP accounting, as U.S. insurers aren't allowed to sit on those reserves anymore. I believe the change was probably tax driven because this was a way of kind of saying these are our liabilities, and future liabilities, but you can't sit on them anymore. I remember it had a dramatic impact.

One jurisdiction, I think it's Singapore, suddenly said a couple of years ago, actually, we're going to let you store up reserves here, presumably as they saw it as a way of getting companies and capital to be based there.

The thing about mechanisms such as Cat bonds, and any of what the insurance industry calls “alternative capital”, (basically a lot of banks or pension funds), is that they want very monolined simple risks they can understand and that are highly modifiable, which is why Cat bonds exist. Actually, I think there have been more Cat bonds issued in the first six months of 2020 than there were in the entire of 2019, so maybe there is capital swimming around that wants to invest, but capital goes to those because of the model-ability of the risk — it seldom goes into anything relating to intangible risks.

Jason Channell: *So even something as tangible as a supply chain is too complicated?*

Dame Inga Beale: Yes, and when we started doing work on supply chain insurance, and this was about 10 years ago, we introduced an insurance policy, but the data we wanted from the corporates in terms of them understanding their own supply chains wasn't available. So we hardly sold a policy, because they didn't understand their own supply chain and they didn't understand where they had exposures. I think it's gotten better but it's still not very good.

Jason Channell: *This seems to be a feature of the current landscape, with something of an impasse between corporates and the insurance industry. While corporates might be frustrated that insurers aren’t offering them the products which they actually need, and the insurers might admit they are not very innovative, in the middle is the fact that many corporates themselves don't know their own businesses very well. Maybe there are innovative ways to access capital markets, the equivalent of a corporate Cat bond, for example, and perhaps those things do need to be developed, but we can’t just blame the insurance industry, as there also needs to be a bit of maturation on the corporate side. Much of this has to do with business processes and how business are structured, figuring out where to get the relevant data from, as often it may not be ‘their own’.*

Dame Inga Beale: Yes it does depend on that, and it's usually related to how much they've invested in technology and systems, because it's all about the data they can't access — it's not being put into anything in the first place. I'm always amazed — we talk about the world of big data, but often corporations and the insurance industry as well, don't actually have this data. They should have been collecting it but they don't have it. It’s amazing, particularly when they’re global companies, how these systems are not joined up — the landscape strategies are appalling.

Jason Channell: *The work that's going on now in supply chain mapping is vast, but it's very new and one of the big drivers of it is actually ESG. While in the past you could maybe ‘hide behind’ an incredibly long supply chain that ended up in a far corner of the world, now all it takes to materially damage a brand is one photo on social media. The impact of ESG on supply chains is perhaps best demonstrated in the world of net zero emissions targets as highlighted in our recent report (See The Net Zero Club: When Sustainability Meets Margins & Supply Chains). Some large multinationals are now ‘scoring’ all of their suppliers along the supply chain and if they fall below a certain threshold on particular sustainability metrics, so that they fall behind the trajectory for hitting the targets which they've given their shareholders, they impose penalties in the form of discounts to input pricing. It's very new, but it's therefore forcing everyone down the supply chains to focus on metrics, and to start reporting on them.*

One area of enormous potential is blockchain, which could almost have been designed to track a particular metric through a supply chain — though often the choice of metric itself is the biggest issue.

Dame Inga Beale: Things such as unique identifiers for items and for businesses and addresses, we still don't have that, so it makes it quite difficult for anyone to collect this data. There is in fact a new blockchain reinsurance partnership set up by 12 companies or so to look at the blockchain matrix, and it will be quite interesting to look at how they assess risk.

Jason Channell: *We've looked at some of the challenges and opportunities of pricing systemic risk, but how should investors, banks, and financial institutions go about it? If you sat in a room with a Chief Risk Officer of a major institutional investor or a major global bank, who said, "You price risk. I now have to price systemic risks for mechanisms like the TCFD. Where do I start and how do I do it?" What advice would you give?*

Dame Inga Beale: Well, the simple way we price risk is we look at past experience and we take into account the events which have actually happened in the past, add them all up, and come up with a simple burning cost of that. In the old days that would have probably accounted for perhaps 60 percent of the price. Although everyone would blend it differently, I think nowadays, with things changing so rapidly, that is probably now down to something like only 20 percent of the price. Eighty percent of the price will be your future predictive analytics, where you will be assessing whether an event actually used to happen once every hundred years, but is estimated that it's going to now happen once every 30 years. So then you build that in. That's how we do it. It sounds pretty simple but in a way it is. Then we overlay on that the fact that when it goes into an overall portfolio, can we discount that price because actually the capital we need to allocate to that can be offset because of our diverse cost of capital for everything. If you're very monoline, of course you don't get the diversification benefit, so, you often have to charge more or expect perhaps a lower return. But it's not really much more complicated than that. I mean, obviously there's a lot to be done about predictive analytics and actuarial importance in assessing what will change, and what inflation will do, what the courts will do, availability of personnel and materials and resources and all the rest of it — but it's really fairly simple.

Jason Channell: *Which then begs the question, is the challenge of systemic risk, the obvious one being climate change, that it hasn't happened yet, so we don't have the back data to allow us to price it correctly?*

Dame Beale: Well, no, so we do. For instance, say we're pricing out some windstorm losses — typhoons in Asia perhaps — and we know that with climate change the severity of these is getting much higher, because the sea is warmer and the sea levels have risen. For example Superstorm Sandy cost 30 percent more than it would have done 10 years prior, just because of sea level rises and things like that. So we look at the past and then we'll build in our assumptions about what we know about what climate is doing and how it's changing. So if we think that climate will mean actually, we're going to have to pay more for our water supply because of drought in this certain part of South Africa, we will put that in to our model and say we've got to allow for the claim costing twice as much next year or in 10 years' time. That's how we do it. So actually insurers do already take quite a lot of that into account — the future, looking ahead, and how that will change.

Jason Channell: *So the conundrum here seems to be that the insurance industry has the ability to model it, but the stumbling block is that the liabilities are just so high when we're talking about systemic risk?*

Dame Inga Beale: Yes, and also, there's the uncertainty. So of course actuaries work to a certain level of certainty and if it's too low, then investors would get nervous, whereas insurers tend to have more risk appetite when it comes that.

One last thought is the potential of the mutual side here. So across the global insurance sector, I think the mutual side represents at least a third of all insurance liabilities, and that's a completely different approach, as they're all about giving profits back, rather than making money in the way the rest of the sector is. While Mutuals are not so popular in the U.K. anymore, there are mega-mutuals in Europe, Canada, and in the U.S., and that's a big, big market. It would be interesting to reach out to the ICMIF (International Cooperative and Mutual Insurance Federation) to hear their views.

An Interview with Mark Carney

Mark Carney is currently the U.K. Prime Minister's Finance Adviser for COP26 and UN Special Envoy for Climate Action and Finance. This role focuses on embedding climate into every finance decision and creating a more sustainable financial system to support the path to net zero.

Mark was previously Governor of the Bank of England from 2013 to 2020, and Governor of the Bank of Canada from 2008 to 2013. Internationally, Mark was Chair of the Financial Stability Board from 2011 to 2018, Chair of the Global Economy Meeting and Economic Consultative Committee of the Bank for International Settlements from 2018-2020, and was First Vice-Chair of the European Systemic Risk Board from 2013-2020.

He is a member of the Global Advisory Board of PIMCO, the Group of Thirty, the Foundation Board of the World Economic Forum, as well as the boards of Bloomberg Philanthropies, the Peterson Institute for International Economics and the Hoffman Institute for Global Business and Society at INSEAD.

Jason Channell: *What are the key barriers to incorporating systemic risk into analysis? Why have financial markets historically been so bad at it?*

Mark Carney: Great question. As you know, but it probably bears repeating, systemic risks at the heart are driven by the system itself. And normally there's some form of fallacy of composition and purpose to systemic risk. In other words, they're the sum of individually rational, active actions that cause adverse dynamics. With climate it's straightforward as there's a negative externality, but there's a host of other examples that we've all lived through where something good en masse, or something logical, ultimately becomes a systemic risk. So at the moment we've got a concern for example with paradoxical thrift — the classic paradoxical thrift of individuals, who are logically, understandably, rationally reining in their consumption, but it has the feedback effect of exacerbating the recession. In the financial crisis you had something potentially 'good' which was, through financial engineering, a spread of access to capital into the subprime mortgage market, but there were two amplifications of the collective actions there. One was ultimately that the dynamics in that market eroded the quality of those mortgages, but then of course, it was linked systemically through collateral change and financing, so that they were hidden.

Now to get to the question, this is where the problem lies, because one of the barriers is not seeing the wood for the trees — not seeing those hidden interconnections, which is something which is going to surface with this report, and missing that endogeneity. So sometimes, (and I can understand in the current circumstances of COVID-19), people may think of systemic risk as being an exogenous shock — you know the meteorite hitting equivalent — but really what we're looking at is these interconnections, how they feed back on each other, and how they can often turn something that starts positive, but unless managed appropriately, can become difficult.

Now the other barriers — I'll just list a couple more. I do think that we all have our biases, and biases collecting in the market (particularly if you don't have diversity in the system) discounting knowledge that there is a risk but hoping that, to put it politely, the liquidity illusion, there's a belief that you can get out before the risk crystallizes, or a sort of greater fool theory, which is a common risk of asset management.

Then often there are structural issues in the system which can be a barrier, given liquidity and the way that asset management has grown up. The Bank of England has thought there are some potential systemic risks there, where you have this mismatch between data liquidity and assets that seem liquid, but ultimately it proves not to be the case.

You can argue that in the ESG world, non-ESG investing can help create systemic risk by not focusing on some of these issues that build either climate risks or build societal challenges that ultimately undermine the companies involved, or the system itself. So now, with the growth of and increasing focus on ESG, that brings a different type of risk, which maybe we'll come to, the jump to default social license risk which we see from time to time — but which arguably makes the system more resilient over time.

Jason Channell: *So the natural follow-on question is if these are the barriers, how do we get beyond the myopia of financial markets, and actually incentivize markets to price systemic risk correctly, thereby valuing the sustainability of longer-term returns more appropriately?*

Mark Carney: Well, I think, as with many things in finance, it starts with disclosure and reporting — understanding and having at least the ability to collect the information and make some of these determinations. So we're in the process — the 'collective we', whether it's Citigroup or your clients, the authorities, leading companies — we're in the process of getting companies to disclose, through TCFD disclosures or its variants, scope 1, scope 2, ideally scope 3 emissions. That is a necessary condition you have to have to even begin, and ideally you want all the way to scope three, as you pointed out in your recent Net Zero Club report, so you can start to see some of the most important interlinkages, and common risks or opportunities, depending on how you look at it — that's the first step.

I think another key focus from the TCFD is the sensitivity or scenario analysis that companies should be doing as part of their strategic planning for something like climate, where many of the biggest risks & opportunities are around the transition. That's why we're trying to shape the transition through COP26, but there's lots of actors in that, and lots of variables. So looking at scenario analysis under a smooth transition to a stated objective like sub 2°C, versus abrupt change, and a more business as usual scenario — having these scenario analyses, and disclosure is crucial.

Stress testing is very important as well through the financial sectors. One of the mistakes around sub-prime in retrospect — and I'm not criticizing, as it's obvious to say this with hindsight, and I know Ben Bernanke has made this point a few times — but in the run up to the crisis there were lots of explanations for why this wouldn't be that bad, as opposed to turning it 180 degrees and saying, 'Well, listen, if there is a 30 percent goal on housing, what are the potential knock-on effects and how do they cascade through the system?' So you ask not what you can do to the market, but what the market can do to you. So the discipline around climate — I mean this sounds like an odd thing to say, in terms of ultimately it is fundamental good and what society wants — but the core question is, let's say the world is serious and does pursue policies that are consistent with achieving 1.5°C, the stretch Paris target, the carbon budget is respected, and for the sake of argument it's a smooth transition towards that, but what does that do to various companies' business models, what adjustments do they need to make, and how does that propagate through the system? Which financial institutions have strategies that are robust to this? Where are the opportunities? And really work that through. The scenario where everyone expects it to happen, where it is predictable and credible, now there are challenges with that transition, but in many respects it's the easy transition. In some respects the harder one is instead the climate 'Minsky moment' one, which is where it's more or less business-as-usual for a period of time, and then there's a really forced and abrupt adjustment both on the policy side and financial side down to a low risk of the temperature target, by quite severe policy action. I think investors, companies, all of us, have to be conscious of a jump to default social license, because if you're clearly part of the problem, that which was tolerated a few years ago may not be in the future, particularly under a scenario where society said what it wants. Maybe government doesn't necessarily follow through with the policies, but companies which aren't getting behind it, or aren't part of the solution stick out, when there are more than a vanguard now, but a pretty broad mass of the net zero club, as you termed it, of companies which are getting behind it.

So, just to recap, disclosure, scenario analysis through the financial system, stress testing — all of those processes are tools in and of themselves. What they're doing as well though is they're empowering the board, they're empowering the senior risk managers, and they're getting the CEOs and Chief Investment Officers to really think about these types of risk in a disciplined way.

Jason Channell: *The 'Minsky moment' point is a very good one, as market participants are often somewhat blind to the tipping points which are approaching them, be it European Utilities 5+ years ago with the rise of renewables, or more recently auto manufacturers with the advent of electric vehicles. The view that each of these phenomena was a very small part of industry volumes, and also that cost parity was a long way off totally missed the point. The common mistake is to assume the tipping point comes when the disruptive technology reaches cost parity, but it isn't — it's way before that; it's once the direction of travel becomes abundantly clear, such that the capital expenditure very quickly switches over to the new technology. The capital intensity and long-lived nature of these investments dictates that once the direction of travel becomes clear, corporates would rather invest in a lower-return option but with a greater level of certainty, avoiding what becomes an increasingly obvious risk of investing in stranded assets — the so-called no-regret option. One of the most exciting possibilities about COP26 is the scope for more integrated carbon markets around the world, and I think in a similar way there will be a moment where people see carbon markets are unavoidable, and it's not possible to argue we're not going down that route. At that point the risk associated with carbon-heavy investments starts to go up, which impacts the cost of capital, which then starts to accelerate investment decisions towards low-carbon. So, rather than because of a values-based judgement, it becomes a value-based decision.*

Mark Carney: I think that's right, and that is the ideal transmission, which is that ultimately society says what it values: UN SDGs, getting to net zero declines in climate, and then that starts to get translated into exactly what you said — value — and then the system drives the adjustments. So linking scope three and integrated carbon markets, if we get this right and the thing launches you have not a blueprint, but the actual market. A lot of the low cost solutions, especially reductions, are in emerging and developing economies, so that is natural capitalism. That's something that actually can add some positive momentum to the whole process because, for obvious reasons, you just get the blows to where they're needed in a non-governmental way.

Jason Channell: *Which on reflection is very reminiscent of the UN SDGs, in that they were developed for sovereigns, but actually it's been the private sector that has embraced them and arguably been much more effective.*

So what financial tools can we use to address systemic risks and, in particular, how should we price systemic risk, and what discount rates should we use? Are there lessons that financial markets could learn, for example, from the insurance industry? Given our earlier discussion, is it actually the discount rate we should be looking at, or is that a bit of a red herring on the basis that if we're talking about systemic risk it affects everybody? So if we were thinking about it in a Capital Asset Pricing Model (CAPM) mentality, should our adjustment for systemic risk just go into the risk-free rate so it would impact everyone, or should we actually be looking at the numerator of a returns calculation in terms of the direct impact on the businesses and scenario analysis?

Mark Carney: I think with the sort of classic systemic or macro prudential policies, the tools are there to build prudential buffers. So Citigroup, as you know, has to carry more capital, more liquidity, because it's a systemic bank and, in theory, (I mean it's not thought about this precisely in practice but in theory), that is internalizing some of the externality of your systemic nature, which means, number one, that you're more resilient as one of the important hubs in the system. But it also means that your pricing of additional risk is adjusted accordingly. So prudential buffers.

You want diversity in the system — different types of players, with different risk tolerances, risk-bearing factors, time horizons etc. I think we all know from personal experience that you want diversity in risk management, like literally diversity in background and perspective of individuals and thought processes — we all have blind spots. You do want natural use of scenario analysis and stress tests and what can go wrong.

Now, I'll come to your discount question, because as a regulator, one of the ways you look at cost benefit, around measures to alleviate or mitigate systemic risk, you're often looking at lowering the probability of the event. So if you can shift a financial crisis from a one in 10 year event to a one in 20 year event, obviously that's huge. And you want to lower the severity as well if you can. Some of the measures I mentioned around prudential buffers and others, will help to lower the severity of a systemic risk.

With climate, I think one of the basic points that we've made, and Sarah Breeden (Executive Director for UK Deposit Takers Supervision at the Bank of England) said it the other day, is that ultimately you can't diversify away from climate risk. If in the fullness of time, by the end of the century if we're experiencing these adverse outcomes, the physical risks start to dominate and we're all affected by that in that regard. Now, diversity of technologies and engineering technologies and other forms of carbon abatement, absolutely, so the analogy (with banks and systemic risk) is there but it's less in the financial sector. Certainly the scenario analysis stuff is there.

On discount rates, Janet Yellen (U.S. Treasury Secretary) and I chaired a taskforce with the G30, and we published a report in October 2020, about the interaction between the new financial system — the sustainable financial system that has the reporting risk-return type foundations that you and I know about — and thinking about climate and predictable and credible policy from climate authorities. The analogy through to central banking, is how you pull forward action because you know what the authorities are likely to do. So if you have some predictability about a future carbon price you can pull the effect forward. One of the calculations in that report is, "What's the advantage of pulling forward by a year the date of net zero?" By calculation, five points of GDP is the value of getting there, which cumulatively, that's not nothing to me, and gives you a bit of a bit of a feel. But to flip it around, I'm sure you're familiar with the discount discussion which ultimately gets down to how much we value future generations. I think the sort of Stern-type 1 percent approach, where the pure rate of time preferences is quite low — it's quite a big field the discount question.

Jason Channell: *Given that governments, sovereigns, and supranational are likely to bear the brunt of the financial cost of the immediate response to systemic risks, as we've seen with COVID-19, how can governments ensure they price long-term systemic risk appropriately (or enable the private sector to do so) and avoid short term-ism and capital returns which can make systemic risk either more likely, or more serious? Indeed is managing systemic risk a government issue, or a private sector one, or both?*

Mark Carney: I mean it's certainly both. And certainly both in respect to the fact that from the private side, one of the things you have to think about in terms of managing risk is, when do governments start to take this risk even more seriously, and that's how I'm making my judgement about the climate policy aspect of transition. There's obviously, technological aspects to transition risk and social license aspects as well, and it is a responsibility of governmental boards and the authorities to attempt add-ups of these types of risks to see across the system. That is fundamental. I think there is recognition that quite often in the financial sector, what you're testing for in a stress test or some sort of scenario which you're trying to manage, is not what's going to happen but, in and of itself that discipline is valuable — the line that 'plans are useless, but planning is essential' — that process is valuable. We certainly were in a position because of general stress testing and Brexit stress testing, in effect, that when COVID-19 hit for the financial sector, I mean it was a different shock, obviously, but the capital liquidity, the risk management, the understanding of the positions where there were common ones, it was very current, and not just to the authorities, but also to the main players in the financial sector as well. So it was exceptionally smooth as an adjustment. There were market issues in certain corners of the market, but the core of it was rock solid, which made a difference — risk didn't crystallize. So I do think it's both. I think with the private sector, you do have to think about these risks, they are lower probability but high impact events, it's absolutely difficult to call the timing on them, and there are interconnections and interlinkages that we all don't see. If you're on the Investment Committee or the board, you're the CEO, CIO, you want to know how resilient your portfolios are — whether it's real assets or financial assets — to some of these potential shocks, and then make a judgement that you're willing to take that risk, but you want to ask the question.

Jason Channell: *You spoke earlier about the ability of central banks to influence markets and behavior in advance by 'signaling' on interest rate policy and similar. Is the chief role of sovereigns, governments, and authorities in this situation actually just to signal, very clearly, leaving no room for doubt, the direction of travel in terms of carbon or climate policy, on the basis that the private capital will move faster and more effectively with a long-term planning position?*

Mark Carney: I think that would be amazingly powerful to do that. I think there is a sense at the sharp end of the market that is where we're headed, and a greater understanding that it's where we have to head. I mean after all, you can't stabilize the temperature at any level unless you get to net zero, so at some point the stock has to stop growing if we're going to stabilize it, that's the imperative of climate physics. So, the more credible the government is on that in terms of climate policy, and in terms of financial policy, the better, for example making sure there is common disclosure, making sure you are stress testing your system against climate risks, so there is that strategic resilience. Also, when making fiscal decisions, ensuring a material proportion of those are supporting the industries of the future. I mean, you made the point earlier about the cost of capital and how that shifts when there is upside to application and the technology or, if you build it, it will be used, as opposed to potentially stranded. That's very powerful and the more that is clear, the more effective.

An example of that is effectively the 2035 mandate for no new internal combustion engine vehicles in Europe or the U.K. That's a pretty clear signal, obviously, and the extent to which that is brought forward, it's even clearer. The extent to which there is support in the German budget for the electric vehicle industry, but none for the internal combustion industry — that's pretty clear as well, as is the extent of pledging for a charging station program — again that's clear. All of that says 'growth, growth, growth,' in one area, and predictability and credibility of policy in all respects that just tells the market, or lets the market decide where it wants to put its money, but does pull forward adjustment. If you can get into that virtuous cycle, where the market has the information, governments have the credibility, you have to do less. Less immediately, you can have a smoother policy path.

Jason Channell: *So, with COP26 coming up this year, presumably we can expect a lot more sovereign net zero commitments coming out, assuming we're going to be pushing for integrated carbon markets. But one fascinating area is that we now only respect net zero targets on a scope 3 basis from corporates, whereas most sovereign net zero targets are only on a scope 1 basis. So why will we accept purely scope 1 from sovereigns, and to what extent do we think that will start to change? Will we start to consider economic risks for sovereigns which are very heavily exposed to commodities exports — presumably we'll see that start to come much more into the mix?*

Mark Carney: Very interesting. Well, we have the shift in financial markets that's going on right now in terms of financed emissions by banks, whereas a few years ago, a bank moving towards net zero was its own emissions. Now, reporting around financed emissions, you can see the direction of travel and we'd like to get there in a sensible way by COP26 with financial institutions, so they have a sense of not just their emissions, their financed or invested emissions, but what is the direction of travel of those emissions. So how many of those emissions are on a path towards net zero, and for the companies they are invested in, you can say whether they are on a scope 1, scope 2, or scope 3 basis. But it's not there for countries as you know, though certainly there's a greater appreciation of imported emissions and the track record of countries on that basis. A carbon border adjustment tax is another thing which will get more scope, and I think you have to be aware of the direction of travel. If your emissions are exposed, in other words you have an industry whether it's upstream or downstream that is heavy emitting, well, by definition it's going to go away, or we're not going to get to where we need to get to.

Jason Channell: *So in conclusion, what's the one bit of advice you'd give people on where to start incorporating systemic risk into investment decisions?*

Mark Carney: I'll repeat the line from Eisenhower: "Plans are useless but planning essential." That looking through the scenario analysis, really thinking about it, and taking things at face value that we are going to go to net zero in some way, shape or form, so where are the risks and opportunities for that, it likely will pay to get ahead of the curve on that. Obviously the spirit of what we're trying to do is get this right for the financial sector and so we need the sharp end to be focused on making sure the reporting is right, and people are building these types of skills. Then we need to get on with it, and the power of it is incredible once it's unleashed.

Solutions for Addressing Systemic Risk

What can we learn from the insights of these two leading lights from the world of risk? The key takeaways from our illuminating conversation with Mark Carney seem to be as follows.

- **Scenario analysis and stress testing are essential to understanding the risks and opportunities.** The scenarios should encompass business-as-usual, a smooth transition, as well as 'Minsky moment' scenarios incorporating abrupt change on the policy and financial sides, and on the social side in terms of loss of social license to operate.

- **Common disclosure and reporting**, for climate change specifically, on a scope 1, 2, and 3 basis are a critical starting point.

- **Building risk-management skills**, including diversity of background, perspective and thought processes, time horizons, and risk tolerances can reduce blind spots and biases in these processes; in particular getting beyond the 'greater fool' theory, and the naïve belief that market participants will be able to 'get out' before systemic risk materializes. Understanding mismatches between data liquidity and expected asset liquidity when systemic risk strikes is also key.

- **Improved understanding of corporate strategic resilience and resiliency of portfolios and assets**, whether physical or financial, to low-frequency, high-impact events with uncertain timings and interconnections and interlinkages which are not immediately apparent should result from a combination of the above points, providing the opportunity to take corrective action, via prudential buffers, strategic re-alignment etc.

- **Managing systemic risk is an issue for both the public sector and the private sector.** The public sector has an extraordinary ability to signal clearly the pace and direction of travel of public policy, thereby achieving pull-forward effects, much as with central banks and interest rate policy, as these policy actions are transmitted into financial markets, with private capital then essentially making the result a fait accompli. As an example, clear government policies on carbon, with potentially an integrated global carbon market and coordinated and comprehensive scope 3 reporting, would allow natural capitalism to drive the process of change on climate very effectively.

Similarly, the key takeaways from the insurance perspective from our interview with Dame Inga Beale are as follows.

- **Getting more capital into the insurance industry and making that capital stay there.** It appears that a key stumbling block is the quantum of the liabilities versus the amount of capital in the insurance industry. Innovative financial instruments might provide a solution, particularly in a broad and liquid market, which could provide a portfolio/diversification benefit.

- **The balance of players and risk.** It seems the insurance industry is reluctant to cover larger liabilities — having a propensity to step back, because of the government stepping in and providing a backstop — which creates a vicious cycle of a lower propensity to take out insurance. This is in some ways reminiscent of challenges financing the UN SDGs, to which blended finance has often been postulated as a solution.

Blended finance effectively allows different types of capital with different risk appetites to invest collectively in projects, matching risk/return appetites with appropriate risk profiles/tranches. This can 'enable' projects that might otherwise be closed to private capital due to the underlying creditworthiness of the investment, often due to single sovereign, political, technical or asset risk. A novel structure in the insurance industry, with the right (but not too large) level of government involvement, providing a backstop, could encourage private capital and the insurance industry back in. Simplistically, on the basis that the government is otherwise going to have to cover it anyway, it might as well not have to cover all of it, and then it would at least allow the insurance industry and private capital to come in, and reduce, spread, and increase the understanding of that risk.

- **Modelling, scenario analysis, and stress testing.** Lastly, and perhaps most significantly, the importance of modelling and scenario analysis is abundantly clear, as also highlighted by Mark Carney. While we appear to be good at modelling individual risk or individual event risk, we are not nearly so accomplished at modelling systemic risk, especially where that has geographic and temporal ripple effects from the interlinkages of systemic risks discussed earlier in this report. If we understood more accurately the magnitude and likelihood of these risks, and their interlinkages, we would be better placed to price that risk, incorporate it into analysis, fund mitigation, and adaptation, and to therefore deal with it.

In summary, we are all aware of these systemic risks, but seem reluctant to analyze them effectively, and then to take action in advance to reduce the probability of occurrence, the potential severity, and to improve resilience, believing we will have both the time and ability to act later. The COVID-19 pandemic perhaps provides the perfect example of the fallacy of these assumptions. With the correct levels of disclosure and reporting, in combination with scenario analysis and stress testing, alongside clear signaling of policy direction from the public sector, and the necessary amount of capital in the system and the availability of suitable products, (be it insurance or other innovative financial instruments), we could all be significantly better equipped to cope with systemic risk than we currently are.

Practical Solutions for Addressing Systemic Risk

So how does the above translate into a list of action points for individual entities, be they corporates, funds, organizations, or even governments or supranationals, at a systemic level?

The first step in this process is to consider that some of these risks are genuinely preventable, others are, unfortunately, likely to occur, hence we should focus on reducing their frequency and impact, and still others are hard to influence in either way, hence we should provide adaptation solutions. Adopting the right approach to each is critical if we are indeed to achieve an optimal outcome. For example, if we left the 'solution' to individual entities with regards to climate change, we would undoubtedly spend most of our capital on adaptation, thereby ironically making the outcome more likely (or indeed certain). While this might leave us better equipped to deal with the impacts of climate change, this is most definitely not a solution, and would help to create an outcome where we all ultimately lose — in a dramatic and potentially 'final' way.

Any solution must be adaptable for different types of systemic risk, recognizing the interlinkages highlighted earlier and, moreover, the solution should reflect the optimal outcome in terms of its focus on prevention, mitigation, and adaptation.

Moreover, the point raised by Mark Carney earlier regarding individually rational actions leading to systemically negative outcomes, shows that, when it comes to systemic risk, any solution must itself be systemic. So, without going down the 'benevolent dictator' route, we must recognize that it will be necessary to have a solution involving both the public sector and the private sector, and that the public sector (or indirectly, society) will need to effectively force change on the private sector to achieve that systemic solution, and to disincentivize self-interest-driven individual actions.

Solutions for the Private Sector

If we are to identify possible solutions that allow investors, corporates, and supranationals to manage and address global systemic risks, it is first important to understand in detail why we are currently failing to manage these risks. While not an exhaustive list by any means, we believe the key barriers for the private sector are as follows.

1. **Scale, responsibility and moral hazard:** The scale of systemic risks can be overwhelming, resulting in a sense of futility, which, combined with an assumption of government bail-outs, leads to the 'moral hazard' situation.

2. **Complexity:** Failure to understand, or inability to analyze and quantify the impact global systemic risks could have on an organization.

3. **Costs and benefits of mitigating or adapting to the effects of future global risks are difficult to calculate:** We highlight the problem with the use of different discount rates when calculating the costs and benefits of investing in mitigation and adaptation.

4. **Lack of insurance or other financial products:** While insurance products are widely available for specific risks, products for broader, more systemic risks are either not available or have strict limits or exclusions which can hinder their efficacy for entities attempting to offset potential liabilities.

Taking these points in turn, responsibility and moral hazard are challenges we address later as we believe these are hard for individual organizations to tackle, and instead should be addressed at a systemic level.

The point of scale is inextricably linked with the second point of complexity. Systemic risk is, undoubtedly, an incredibly complex topic with an overwhelming scale, but if it is approached in a structured way, as follows, we believe it is possible to address.

Stage 1: Identification

Much as we have approached the structure of this report, the first stage in any process must be to identify the risks to which an entity is exposed. Frameworks such as that provided by the Cambridge Centre for Risk Studies provide an excellent structure to approach this.

Stage 2: Quantification

Once those risks have been identified, we should try to quantify both their potential impact and the value (or other variable) at risk, as well as considering their likelihood or frequency of occurrence. Both Dame Inga Beale and Mark Carney highlighted the critical importance of scenario analysis and stress testing, which, importantly, are not necessarily the same thing.

Although the assessment of known, emerging, and apparent risks naturally takes precedence in most risk-management exercises, it behooves all managers to consider the impact of long-term, or slow-to-emerge, risks to business, such as the systemic risks highlighted in this report. The current globalized risk landscape is a varied and complex one, but the management of it is possible, as is the quantification of even the most significant and uncommon risks.

Holistic risk management and analysis depends on and combines a number of components, including the arrangement of principal threats, into a taxonomy, the assessment of emerging, novel, and existential threats to macroeconomic systems which may ultimately impact a business' outlook, the development of a library of scenarios, as well as a system of analytics for translating the results of the scenario into actionable tasks for mitigation and risk-appetite setting.

Scenario stress testing is a useful mechanism for an entity to evaluate its capacity to respond to a crisis. That is, creating a hypothetical set of catastrophic occurrences through which to consider risk and its management. Note that scenario stress tests are not predictions. A catastrophe scenario stress test is a 'what-if' illustration of a particular type of disaster.

Scenarios also provide a means for benchmarking and comparing threats. They are a key source of stress testing an organization or the global economy as part of risk or resilience assessment. A single stress test scenario provides a detailed view into what an extreme event could look like, how it would unfold over time, and its direct and indirect effects. This gives a generalist the means to appreciate the potential disruption or damage linked to a certain threat type, while corporates, investors, and policy makers alike can use the outputs to make better informed strategic and risk-management decisions. Key principles are detailed below.

Designing Scenario Stress Tests

The design of stress test shock scenarios typically aims to construct hypothetical events of such extremity that they are only barely plausible. This is consistent with Lloyd's Realistic Disaster Scenarios, for its syndicated insurance companies, and the U.S. Federal Reserve Board's 'severely adverse scenario' used for regulatory reporting in its Comprehensive Capital Analysis and Review (CCAR).

Using the back catalogue of historical events and the theory and scientific models available, it is possible to design detailed catastrophe (or other) scenarios and estimate their direct and consequential impacts on the system at risk. A detailed scenario, complete with impact assessments, is also a vehicle for asking "conditional what if's" such as, what combination of factors would result in a doubling or halving the loss? The resulting scenario variants give a sensitivity analysis of the system impact with respect to changes in the characteristics of the scenario.

By selecting a handful of metrics for assessing the impact of any shock to that entity, it becomes possible to compare crises and their impacts across threat classes. This is useful to stakeholders for prioritizing prevention and mitigation for certain threats, and drawing attention to threat types whose impacts may otherwise be underrated or even unanticipated.

Impact metrics used in scenario stress testing for macro-catastrophes include macroeconomic variables such as shocks to GDP (see GDP@Risk earlier), national employment figures, balance of payment and interest rates, foreign exchange rates etc. Metrics for more direct human impact include morbidity and mortality, social disruption, and loss of public confidence. Corporate impact could include shocks to demand, revenue, costs, share price, and credit ratings on top of direct damage to operational capacity and consequent reputational damage.

To make qualitative comparisons of different threat types on a given system, it is helpful if the threat severities of all illustrative scenarios are selected to reflect an appropriate frequency or likelihood. For example, by attempting to construct a set of '1-in-100 years' catastrophe scenarios, we can begin a discussion of resilience of our system to events from all sources over the span of a century. This is illustrated in Figure 9 earlier in the report, which lists GDP losses associated with a number of global catastrophes.

We note that the process of constructing frequency-severity data for future events associated with human systems, such as conflicts, and uptake of new technologies, may have a more subjective feel than doing the same for purely physical threats like earthquakes. Impact metrics for scenario stress testing further provide a useful baseline for comparison across threats.

It is essential this process remains in constant motion, subject to renewed interrogation and update throughout the financial calendar, as the nature of globalism means the landscape is continually subject to new threats and new avenues for the conveyance of risk across systems. The benefits of this process are easily demonstrable.

Perhaps the most important principle underlying a stress test scenario is that it embodies relationships and knock-on effects — in other words, correlated losses within the system at risk — hence the focus of this report on the interlinkages of systemic risk. Stress tests embodying systemic correlation are called coherent stress tests.

Examples of Scenario Stress Tests

Chief amongst these long-term, slow-to-emerge risks are those associated with the changing climate, such as increased water and food crises, mass migrations, changes in consumer habits, carbon taxing, and transportation costs etc.

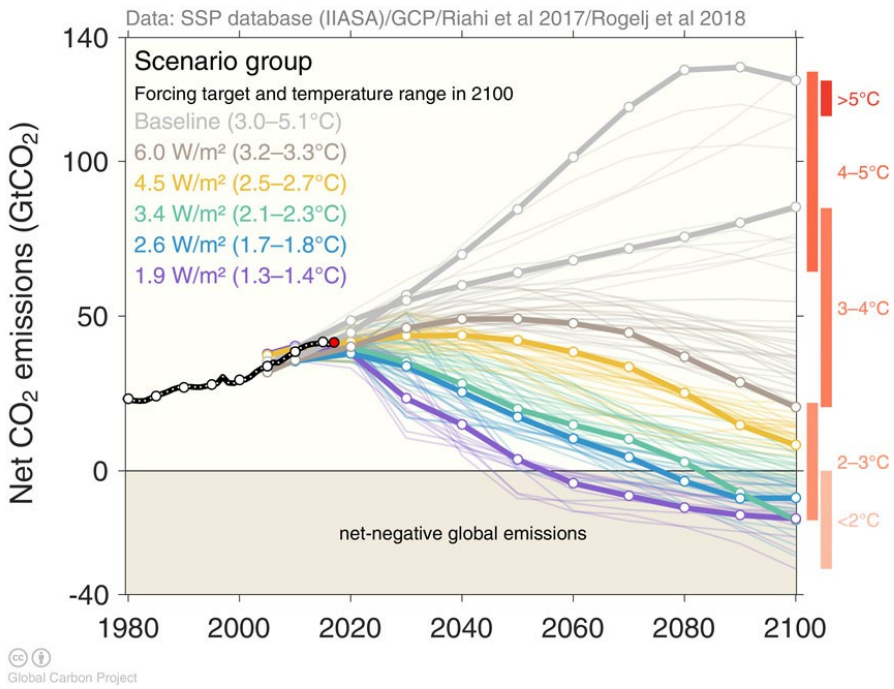
It is necessary for businesses, investors, municipal and national governments, and wider society to remain informed about the nature of climate change's strain on global economic systems, and to discuss mitigation steps early and regularly on the basis of the current science.

This is a rapidly evolving space, being driven not least by the emergence of the TCFD (Task Force on Climate-Related Financial Disclosure) (See Citi GPS: Building a TCFD With Teeth). One such methodology for doing so is to adopt the International Panel on Climate Change (IPCC) scenarios for climate change, termed Representative Concentration Pathways (RCPs), as shown in Figure 18 below, representing the concentration of greenhouse gases in the atmosphere.[63] RCP 1.9 represents the limitation of global warming to below 1.5°C, the goal of the 2016 Paris Agreement. RCP 7 represents the baseline, with a temperature rise of 3°C throughout the 21st century, with RCP 8.5 being the worst possible scenario until the year 2100.

Using RCP scenarios as a range of variants for a company's long-term risk outlooks provides structure for what would otherwise be a challenging process. Understanding that a certain RCP will likely bring with it a certain frequency or impact-threshold of natural hazard risks, and increase the likelihood of a variety of consumer and resourcing risks, provides scientific grounding for an internal long-term risk analysis exercise.

[63] Intergovernmental Panel on Climate Change (IPCC) (2014).

Figure 18. Emission Scenarios and Radiative Forcing Levels for Representative Concentration Pathways (provided by the IPCC)



Source: Carbon Brief

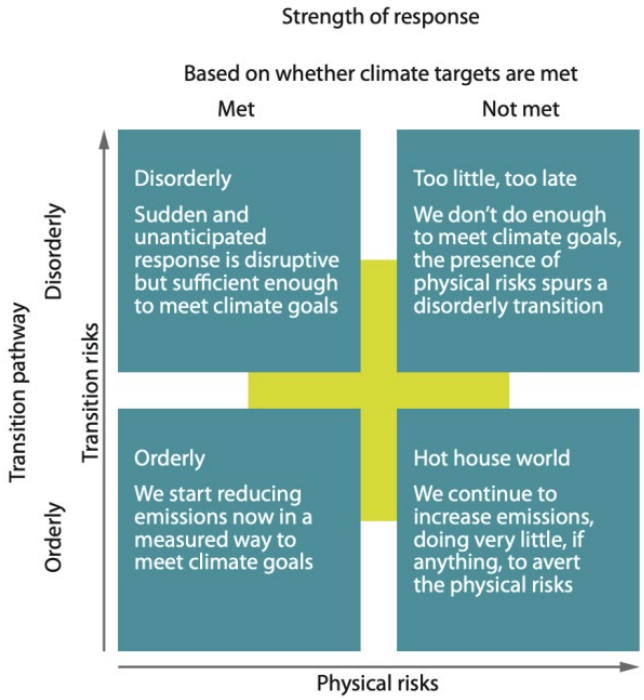
It is important to note there are different types of climate risk — the two key distinctions in the TCFD being physical risk and transition risk. The first of course refers to the exposure of physical assets (such as a factory) to climate-related disasters such as flooding, bush fires, hurricanes, etc. The second, harder to analyze but potentially of greater significance, is so-called 'transition risk'. This refers to the risk to a business (or indeed sovereign or other organization) from the shift of the global of localized economy to a low-carbon future. Clearly, for an entity such as a coal producer, the transition risk is nothing short of existential, which may require a complete rotation (or indeed liquidation) of assets and an entirely new business model, if indeed this is possible (though it may be via technologies or mechanisms such as carbon capture, utilization and storage (CCUS), carbon offsets etc.). For others, it may require partial re-tilting of business models (requiring significant refinancing), asset sales, or the inclusion of anticipated carbon taxes, with different carbon price scenarios giving in some cases a relatively simple idea of financial exposure.

Alongside the TCFD is the 'NGFS' or Network for Greening the Financial System, which is rapidly emerging as a go-to source for financial institutions seeking guidance on reporting climate exposures and designing associated scenarios and stress testing.

The NGFS consists of 83 members (mainly central banks, and financial supervisory authorities) and 13 'observers' (typically supranationals such as regional development banks, the Bank of International Settlements (BIS), Organisation for Economic Co-Operation and Development (OECD), World Bank/IFC etc.). The NGFS was designed primarily as a tool for central bankers to strengthen the global response to the Paris Agreement, as well as improving the ability of the financial system to manage risks, while developing markets and facilitating capital flows into 'green' and sustainable investments.

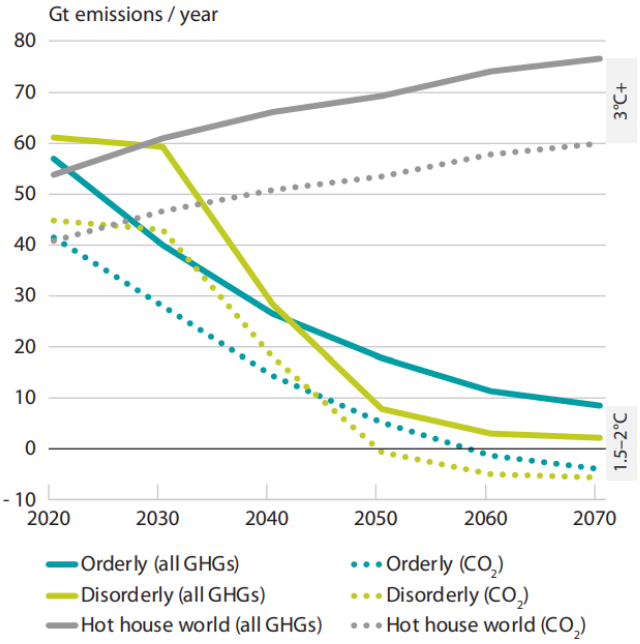
The detailed scenario approaches proffered by the NGFS are rapidly becoming seen as something of a go-to source for climate-related stress testing (alongside the TCFD), as outlined in Figure 19 and Figure 20).

Figure 19. NGFS Climate Scenarios Framework



Source: NGFS (2019)

Figure 20. NGFS Representative Scenarios for Emission



Source: IIASA, NGFS Climate Scenarios Database, using marker models

The approach consists of three representative scenarios, covering orderly, disorderly, and 'hot-house world' scenarios, while the fourth 'too-little, too-late' scenario, with significant physical and transition disruption, was not included in the first iteration. These scenarios are then mapped into potential greenhouse gas (GHG) emission scenarios with associated transition pathways, and then further translated to GDP@Risk metrics etc. via Integrated Assessment Models (IAMs), which provide 'internally consistent estimates across economic, energy, land-use and climate systems' (NGFS) including assumptions of socioeconomic variables, technological development, policy, etc.

The Limitations of Stress Testing

There are, of course, numerous limitations to scenario stress tests. Not least is the extraordinary complexity of global systems, the interlinkages, and the fact that many of the systemic risks in question (such as climate change) have not actually (fully) happened yet, so we have little empirical data to work from.

The NGFS highlights current gaps in its scenario modelling, bracketing them into three key areas, namely scope, coherence and uncertainty. Scope refers to the issues of converting 'global models' down to individual countries, let alone industries or individual companies, as well as the scope of modelling outputs, and the linkage of those outputs to financial risks, the transition mechanisms of which are likely to vary widely. Coherence refers to the challenges of integrating modelling across physical and transition risks, as well as, more generally, the comparability of assumptions, models, scenarios etc., especially as relates to integrated asset models (IAMs).

The last is perhaps the most obvious, as well as most significant — namely, the challenges of quantifying uncertainty, as well as the aforementioned issues in terms of assessing the quantum of risks/impacts from physical and transition risks, given the extraordinary complexity of systems. To this we would add the focus of this report, in that while IAMs might offer integrated approaches, the permutations and combinations and multiplier effects as we delve into the interlinkages of risks, not least combining the variables of policy and technology response, and human behavior, mean that developing credible scenarios is incredibly challenging. Nevertheless, the provision of scenarios by organizations such as the NGFS is an important first stage in creating a common system of analysis which will hopefully, in turn, facilitate standardized reporting, which allows investors, policymakers and others to compare exposures, assess weak links in the system, and decide which challenges to tackle first.

Stage 3: Solutions

It is only having identified, understood, and quantified our exposure to risk, that we can start to consider possible solutions and, importantly, to assess the cost/return implications of the various ways of addressing these risks.

As mentioned previously, there are three generally recognized options:

1. Prevention;
2. Mitigation, in financial, business, environmental or human terms; and
3. Adaptation, both physically, operationally, financially and strategically.

Clearly, prevention is the preferred option, all things being equal, but if a risk cannot be eradicated or avoided, limiting its impact via 'mitigation' is the next best option. And, if we can't do that, then we simply have to adapt or learn to live with it.

Taking these in reverse order, adapting to systemic risk might be the 'last option' but it is in many ways the easiest — it is the 'sit tight and hope it doesn't happen to me' option, or simply thinking we'll deal with whatever when it comes. The COVID-19 pandemic provides a salutary lesson, in that as discussed earlier, we can hardly say that a pandemic was wholly unexpected, yet we chose not to prepare adequately, and have arguably spent infinitely more in tackling the pandemic ($15 trillion and counting) than we might have had to spend to avoid it in the first place. Tackling climate change presents another perfect example; even though we now (generally) accept it is happening, we are still reluctant to spend the money on reducing emissions now before climate change actually occurs, apparently preferring to spend much more on adapting to life in a hot-house world, if indeed we can, spending our money building sea defenses and tackling all of the other knock-on effects such as famine, drought, and mass climate migration, to name but a few. To be fair, there is always pressing need for investment, which may take precedence, particularly from a short-term political perspective, and a finite amount of capital — although once again, COVID-19 demonstrates that we can find the money when we really need to.

Adaptation and Mitigation Options

Mitigating the impacts, or adapting to the effects of systemic risk could be approached in numerous ways depending on the risk in question, the nature of the organization, and the level of its exposure, so it is clearly not possible to delve into individual solutions here.

However, it is important to understand the implications of these risks, as these may require different types of solutions, as for example in the case of the two elements of climate risk, namely physical risks and transition risks. Physical risks are likely to require physical solutions, such as flood defenses, or at the extreme, relocation of operations. Transition risks may require options such as corporate restructuring, asset sales/purchases as part of a strategic realignment, investment in R&D or new technologies. Finally, for some risks that are not possible to mitigate or adapt to physically or structurally, there may be a need for financial restructuring, either through considerations of broader and more stable supply chains (potentially incorporating increased working capital), having redundancy solutions in place (for example disaster recovery operational centers), greater financial buffers in the vein of capital adequacy requirements and, finally insurance products that can improve financial resilience.

The decision process for all of these solutions is going to incorporate an element of cost/benefit and risk/return analysis, as with all financial decisions, and a key element will be the choice of discount rate applied in those decisions. While this is a vast topic in its own right, which has been raging for years in the case of climate change, we highlight the key challenges below.

Discounting the Future

A key element of assessing the relative costs and benefits of investing now to limit the impact in the future is the rate at which we discount those future benefits (or avoided costs) back to current values, and often determines whether a project passes the benefit-cost test. This is especially true of projects with long-term horizons, such as those to reduce greenhouse gas emissions or investing in mitigating any other global risk. Whether the benefit of investing in ways to mitigate global risks happening — such as climate change or even investing in ensuring a global pandemic never happens again — outweigh the costs, many of which are borne today, is especially sensitive to the rate at which future benefits are discounted. The appropriate social discount rate and the way it is calculated has long been a source of disagreement amongst economists. These disagreements came to the forefront when the Stern Review on the Economics of Climate change was published. Stern in his calculation used a discount rate of 1.4%, while other economists such as Nordhaus used a long-term discount rate of 4.5%. These opposing views lead to completely different perspectives on the appropriate level of climate change mitigation.[64]

Economists advocate the social discount rate should be primarily determined by the opportunity cost of capital, which is determined by the rate of return on alternative investment. However, others hold it is unethical to discount the welfare of future generations, and therefore a lower discount rate should be used to calculate the present value of future climate damages. Figure 21 below shows the climate change damages we calculated in our Energy Darwinism II report based on different discount rates (Citi GPS: Energy Darwinism II - Why a Low Carbon Future Doesn't Have to Cost the Earth). As the table shows, a low discount rate encourages early action primarily because future damages count for so much.

[64] Drupp et al. (2018).

Figure 21. Cumulative Climate Change Damage (loss to Global GDP between 2015 and 2060)

Discount Rate	PV of Damages (lower bound)	PV of Damages (central)	PV of Damages (upper bound)
	US$ Trillions	US$ Trillions	US$ Trillions
0%	-20	-44	-72
1%	-14	-31	-50
3%	-7	-16	-25
5%	-4	-8	-13
7%	-2	-5	-7

Source: Citi GPS

Not only is finding the correct discount rate difficult to determine, but there is also debate about whether the liabilities versus cost of avoidance should be discounted at different rates, or whether we should use a discount rate that reflects the actual market opportunities that societies face. A survey was conducted by Drupp et al. in 2018 to understand the different views of economists. It found that many recommended a median discount rate of 2.3%. Other experts, such as Freeman and Groom (2016)[65] and Arrow et al. (2013)[66], suggest we should use social discount rates that decline over time, giving more weight to future generations.

Moreover, at an organization level, our first port of call for addressing systemic risk might be to examine the classic risk/return relationship—for a higher level of risk we require a higher rate of return to compensate—and the way we would traditionally capture that concept is by using a higher discount rate from the higher cost of capital, reflecting that higher risk. Incorporating risk should divert capital via risk-adjusted returns to better outcomes, and withdraw funding from higher-risk activities by making the cost of capital higher, and the resulting return spreads less attractive.

So, it might seem that the easiest and most obvious way to incorporate systemic risk into final calculations and decisions is simply to adjust the discount rate via the inclusion of a risk premium. This approach is however fraught with issues. If we consider how a discount rate is formed, using a WACC (the weighted average cost of capital), the first element of that, namely the cost of debt, 'is what it is', and moreover, trying to work out how much of a risk may or may not already be reflected in that cost of debt is a tricky operation. The cost of equity consists of a risk-free rate (which again 'is what it is'), which we adjust via an equity risk premium (promising….), itself adjusted by a so-called 'beta' which reflects the relative volatility of an instrument in question (compared to, say, the local stock market index). The issue here is that an equity risk premium is calculated by means of assessing the likely excess returns of equity versus a risk-free investment (usually a long-term government bond), while the beta is calculated by looking at the covariance of a financial stream versus the variance of its benchmark. In simple terms, calculating both requires us to estimate the relative return or volatility of a financial stream, which is impacted by a risk event, versus one which is not; which brings us right back to square one. If we are going to have to assess the financial impact of a risk occurring (via means examined in our discussion of stress tests and scenarios), we might just as well use that impact figure as the 'answer' — rather than using it to adjust a discount rate, which we then apply to the 'unimpacted' revenue stream to produce a 'value at risk' figure. It is effectively a convoluted and much more complex way of getting to the same number.

[65] Freeman and Groom (2016).
[66] Arrow et al. (2013).

So, all roads seem to lead back to scenario analysis, and directly examining the value at risk, as discussed earlier in the GDP@Risk methodology from Cambridge, which estimates economic losses of various threats to cities[67] and the global economy,[68],[69], and the importance of scenario modelling and stress testing cannot be overstated.

The Importance of Insurance and Mutualization as Part of Mitigation and Adaptation

It is of course impossible to prevent and mitigate all risks, hence there will always be an element of learning to live with risk; indeed this is where insurance comes into the equation. If an organization is not able to prevent or sufficiently mitigate risk to itself, a typical response is to insure itself against the outstanding effects, improving financial resilience, thereby allowing itself to mitigate the impact, or potentially to use an insurance payout to allow it to adapt to the reality of the insured risk materializing. By mutualizing those risks across society, the right insurance products can spread the economic burden of adaptation such that no one entity that is unlucky to feel the effects is bankrupted or broken by the misfortune of being the one who suffers the effects.

The challenge here, as highlighted by Dame Inga Beale, is that there is simply a lack of appropriate insurance products, for a variety of reasons. First, the complexity and interlinkages of systemic risks means the detailed modelling and understanding of potential liabilities, alongside frequency of occurrence makes this challenging. Moreover, the fact that many of these risks are have not yet occurred (or have, but not at a systemic level) means there is a lack of empirical data on which to base these calculations. However, as Dame Inga Beale points out, we actually do have much of the data to undertake these calculations and with the right will, it is therefore theoretically possible to design and price appropriate protection. A greater issue, however, is the lack of capital in the industry, certainly when considered relative to the scale of the potential liabilities, which, as Dame Inga Beale points out, is due partly to a 'chicken-and-egg' issue of a lack of products in emerging markets, and not least the issue of moral hazard and an assumption of government bailouts (both by the underwriter and the underwritten). If others are not insuring themselves and expect to bailed out by governments, why would we undergo the expense of taking out insurance ourselves? And, if we won't take out insurance, as we don't need to (as governments will bail us out), why would insurance companies offer it — especially if the uptake is not broad enough to get enough capital into the industry to underwrite the potential payouts. This vicious circle of lack of cover and lack of capital combined with the moral hazard argument means that a more integrated public/private solution may well be necessary, as examined in the next chapter.

[67] Cambridge Centre for Risk Studies (2018).
[68] Ruffle et al. (2014).
[69] Bowman et al. (2014).

Challenges for the Public Sector

By their very nature, systemic risks will impact an entire system and, hence, will largely impact all of us. As such, should we even attempt to deal with systemic risk on a bottom-up basis, or, rather, should we try to tackle it on a top-down basis? While action obviously starts with one person, it is questionable as to how much impact any one entity, acting alone, can have on mitigating, let alone preventing, systemic risk; whereas collective and especially more coordinated action certainly could. So it seems clear that to truly tackle systemic risk, we need both bottom-up and top-down action.

The Barriers to Collective Action

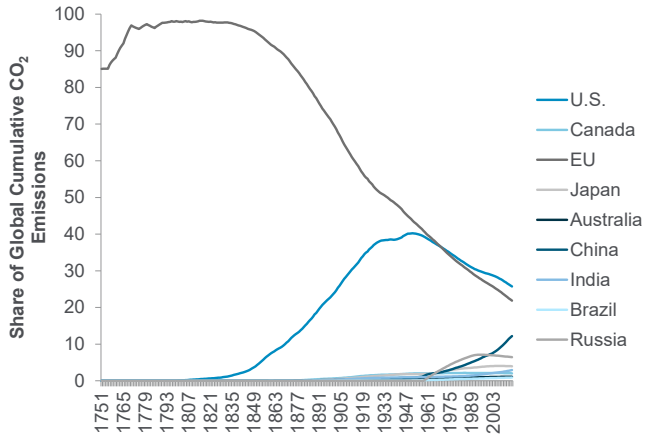
The Tragedy of the Commons

The issue with collective or more coordinated action is the 'tragedy of the commons', as highlighted by Mark Carney. The tragedy of the commons refers to the over-exploitation of common resources, in that no one country, company or individual feels motivated to make sacrifices or to change their behavior for the common good. It captures the idea that resources that do not clearly belong to an individual or a group are likely to be over-exploited, since conserving them is in no individual's interest. Examples include the oceans, rainforests, the atmosphere, and the air that we breathe — all of which are perceived as common resources without any national boundaries.

On the global stage, one of the biggest tragedies of the commons is of course climate change. Despite academics and scientists repeatedly stating the impacts of climate change could be drastic for the global economy and the livelihoods of people, countries have delayed taking real action for decades, quarreling over costs and responsibility. Countries have an incentive to be free riders and avoid reducing emissions, as long as they feel that other nations are acting to reduce their emissions. The problem of course is that emissions affect every country, regardless of where the emissions are actually generated. Reductions in emissions in one country would make minimal difference to the domestic exposure of climate change impacts with the exception of a number of countries that are large emitters, such as China and the U.S.[70] The Paris Agreement did create a movement for change, with many countries committing to reduce their emissions, including now the U.S.

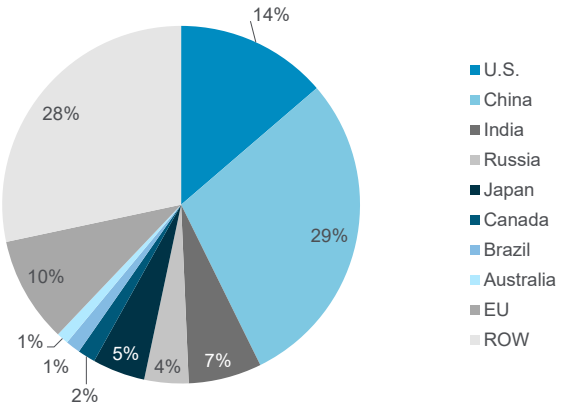
[70] Ian Golden (2013).

Figure 22. Share of Global Cumulative CO_2 Emission



Source: Citi GPS

Figure 23. Share of Annual Energy-Related CO_2 Emissions in 2017



Source: Citi GPS

It is not only climate change that falls in the category of the tragedy of the commons, other resources such as biodiversity, water etc. are also affected by the global commons. The real tragedy of the commons is not only that it makes collective action harder to achieve, but perhaps that we can actually make these catastrophes more likely to occur, and increase their severity, by acting alone — whereas with more coordinated and centralized response, we can actually reduce their likelihood of occurring in the first place. Which is why we believe that, while considering what adaptation might look like, and indeed ensuring we are adequately prepared and insured, if we are truly to tackle systemic risks, the solutions must be, by definition, systemic in their nature.

National Governments

National governments and policymakers often have a very linear view of the world; many believe that just by using the right levers they can ultimately get the economy and society back on track after a crisis has occurred. However, this approach ignores completely the complexity of global systemic risks and ignores how systems interact. For example, a decade of under-investing in public health services around the world either due to public cuts, privatization, or other reasons has in many countries affected the response to the COVID-19 crisis. In other words, tackling one issue such as debt and reducing public spending over the long term, can affect the response needed by different public bodies to tackle complex global systemic risks.

Managing systemic risks, especially for governments that are set up around traditional threats that are no longer today's greatest concern is a major problem. Risks that occur from biology, the environment, domains of technology etc. do not fall into the traditional governmental view of the world. These risks, as we stated before, are complex, varied, global, interconnected, and could be catastrophic. They could take decades to arise, which conflicts with the political time scales of national governments. Most national governments have a very short-term view of the world, which largely corresponds to their time in office, and therefore investing in issues that go beyond this timeframe is rarely done, as successes on long-term projects could fall to their political rivals.

Most of these risks such as climate change or biodiversity loss are also not nationally confined, meaning they would benefit everyone.[71] When such benefits are dispersed and the costs immediate, it is tempting for many governments to hope others will pick up the slack, hence the tragedy of the commons discussed previously. While global threats are escalating, many key governments are also turning their backs on the international system. They have, in fact, over the years starved most of these institutions of funds needed for them to modernize.[72] So, even though global institutions do need to reform, as described below, there is a need for more capital to be invested for these reforms to take place, so that ultimately the world can be prepared to deal with future global systemic risks. National governments cannot do it alone; we also need global institutions to coordinate international efforts to reduce systemic risks.

The Ability of Global Institutions to Manage 21st Century Systemic Risks

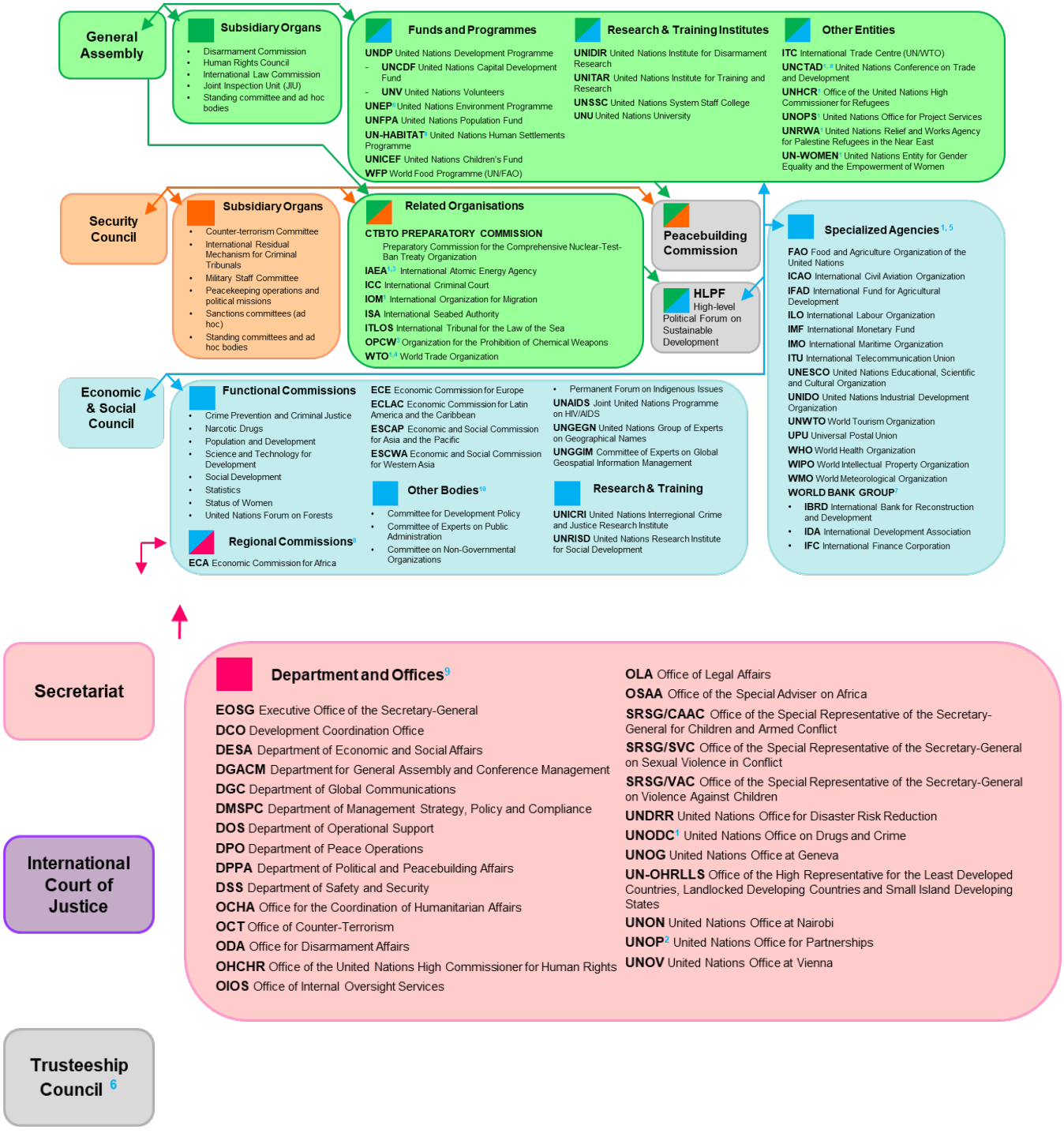
Many of today's global institutions were set up to deal with problems and issues that were relevant in the 20th century. However, since then, the world has changed dramatically, with population and urbanization increasing, the world becoming infinitely more connected, and technological innovation dramatically changing the way we live. The challenges of the 21st century seem be characterized more by interconnectedness rather than isolation; they require systems thinking alongside the integration of knowledge from natural sciences, social sciences, and humanities.[73]

There are a small number of international institutions that have dominated the international scene over the last 60 or 70 years. The United Nations (UN), set up in 1945 to replace the League of Nations, was created to promote peace and to create a forum for negotiation between states. The structure of the UN is enormously complex, as shown in the diagram below, with the General Assembly and the Security Council being the central parts of the organization. However, the UN also includes over 20 agencies, including the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the UN Human Rights Council (UNHRC) and the UN Development Programme (UNDP). Most of these agencies are designed to work on specific issues, however as Ian Goldin states in this book 'Divided Nations', together these agencies "represent a spaghetti bowl of overlapping mandates".[74] Agencies that are created for one reason are adapted to fill new niches, and in many cases the mandates have sprawled in a number of different directions to address new issues or various key donors' changing interests. In fact, some UN agencies rely on donors to fund their projects, and this means they focus more of their time on donor-led projects and can therefore find it challenging to focus on new problems.

The Bretton Woods Institutions, which include the World Bank and the International Monetary Fund (IMF), have different mandates, including the alleviation of poverty and exchange rate stability, respectively, though over the years their mandates have increased substantially to include everything from financial regulation to climate change.

[71] Recchia and Belfield (2019).
[72] Ian Goldin (2020).
[73] Bradford (2005).
[74] Goldin (2013).

Figure 24. The United Nations System



Notes: (1) Member of the United Nations System Chief Executive Board for Coordination (CEB). (2) UN Office for Partnerships (UNOPO) is the UN's focal point vis-à-vis the United Nations Foundation Inc. (3) IAEA and OPCW report to the Security Council and the General Assembly (GA). (4) WTO has no reporting obligation to the GA, but contributes on an ad hoc basis to GA and Economic and Social Council (ECOSOC) work on, inter alia, finance and development issues. (5) Specialized agencies are autonomous organizations while work is coordinated through ECOSOC (intergovernmental level) and CEB (intersecretariat level). (6) The Trusteeship Council suspended operation on November 1, 1994, as on October 1, 1994 Palau, the last United National Trust Territory, became independent). (7) International Centre for Settlement of Investment Disputes (ICSID) and Multilateral Investment Guarantee Agency (MIGA) are not specialized agencies in accordance with Articles 57 and 63 of the Charter, but are part of the World Bank Group. (8) The secretariats of these organs are part of the UN Secretariat. (9) The secretariat also includes the following offices; The Ethics Office, United Nations Ombudsman and Mediation Services, and the Office of Administration of Justice. (10) For a complete list of ECOSOC Subsidiary Bodies see un.org/ecosoc.
Source: Citi Global Insights

The structure of these institutions has changed little over the years, the main difference now being that they have many more members, and they largely represent the countries with the most international power many years ago. For example, the UN Security Council consists of five permanent member states including China, the U.S., France, the U.K. and Russia, all of whom have the privilege of a veto, and ten non-permanent member states which are elected for two-year terms by the General Assembly. There have been many[75] who have criticized the fact that the Security Council does not represent current geopolitical realities, and regional powers such as Brazil, Germany, India, Japan, South Africa and Nigeria have sought to secure permanent seats of their own.[76] Non-permanent members are also being relegated to rubber stamping decisions by the permanent members or choosing between different positions. Public vetoes or even the threat of using a veto privately by permanent member states can halt the Security Council in acting to resolve many crises.[77]

Many of the global institutions that we have today are not really set up to meet the challenges of the 21st century. For one, effectiveness is crucial when dealing with a crisis, and having to negotiate between close to 200 countries in some UN agencies makes it challenging to produce decisive action. Many of these institutions also lack the authority, capacity, or legitimacy to deliver the enormous expectations placed on them, not least in global systemic risk management.[78] This does not mean they have not done some extraordinary work in maintaining peace, nor that they have not been instrumental in reducing poverty. To its credit, the UN has managed the extraordinary achievement of getting countries to commit to reducing their CO_2 emissions over time, though whether these commitments will be fully honored, only time will tell.

There are other institutions such as the G7 that also play an important part in managing systemic risk. The G7, originally the G8, was set up in 1975 with the aim of bringing together the leaders of the world's leading industrial nations to discuss issues such as global economic governance, international security, and energy policy. It is comprised of the seven largest so-called advanced economies: Canada, France, Germany, Italy, Japan, the U.K., and the U.S. The President of the EU Commission and the President of the European Council also attend the meetings. There are many who are highly critical of the effectiveness of the G7, especially since it excludes countries such as Brazil, India, Australia, and China, and therefore believe it cannot possibly claim the legitimacy required to exercise global leadership.[79] Therefore, many ask whether the current G7 is capable of addressing global systemic risks, such as climate change, nuclear proliferation etc., as there are hardly any issues that can be solved without the help of non-G7 countries. The G20 in this regard might be argued to be better placed to address global 21st century issues, looking like an appropriate vehicle for facilitating global dialogue as its membership represents 85 percent of global GDP. However, according to Chatham House, it has proven to be 'utterly incapable of advancing any solutions' to global challenges.[80]

[75] Lattila (2019).
[76] Council on Foreign Relations (2020).
[77] Lattila (2019).
[78] Goldin (2013).
[79] Chatham House (2018).
[80] Chatham House (2019).

As we face more global threats including pandemics, security crises, and climate change, new approaches to global governance are needed. It is very difficult to manage systemic risks without global coordination, collaboration, and effective national governance. This is illustrated in the way individual countries have managed the COVID-19 pandemic, with countries competing with each other to acquire testing capabilities or protective gear, rather than working collaboratively to solve these problems. Collective action and good global governance could have potentially reduced some of these problems. Scientists and medical staff in their quest to find a cure or vaccine have shown that global collaboration can make a huge difference to outcomes. Governance reform of existing global institutions is both essential and well overdue.

Systemic Solutions for Systemic Risks

We have seen the approaches companies or other organizations should take regarding their own preparedness to deal with systemic risks, namely identifying and understanding the risks which face and impact them, quantifying them, then undertaking measures to prevent or mitigate their impact, and if these are not appropriate, to adapt to these occurrences. We have seen this could entail everything from structural, financial, geographic, and strategic realignment and the important role insurance can play for those risks (or tail elements of which) it is not possible to offset by any other means.

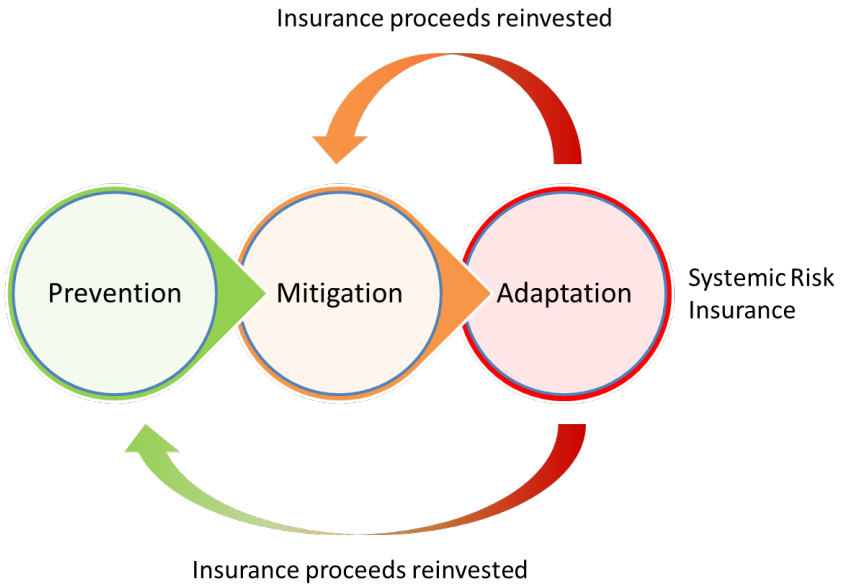
But we have also seen that individually rational actions can, by their very nature, actually make systemic risks more likely to occur, and hence to truly address systemic risk, collective and coordinated action will be required. Moreover, adaptation is itself not a solution and should be seen as the last resort, not the first, and measures aimed at prevention (or at worst mitigation) would be the most logical solution — at a collective or coordinated approach. Put simply, systemic risks will require systemic solutions if we are truly to prevent their occurrence. We can choose to adapt and mitigate individually, or to prevent collectively.

Much of the approach currently provided by the insurance industry clearly deals with adapting to, or increasing resilience to the effects of systemic risks manifesting themselves. While this is undeniably important, from a systemic solution perspective we shouldn't allow this to inadvertently create that combination of individually rational actions which lead to a systemically sub-optimal outcome, by ironically causing the systemic risk to materialize. So how do we evolve the approach to adaptation, such that it can also provide a solution to the problem of prevention?

Finance might provide the solution here, working in conjunction with both the private sector and the public sector. The first thing which is needed (beyond the will, which we will take as read) is capital. The reluctance to take out insurance against systemic risks is both a function of a lack of suitable insurance products, as highlighted by Dame Inga Beale, in part due to a lack of capital in the system, and the perception of government bailouts, which creates a vicious cycle. If we could turn that vicious circle into a virtuous circle reminiscent of blended finance, whereby government would signal a backstop, but with clearly defined limits, this could then attract in private capital from insurers. Moreover, a clearly limited government liability would be beneficial to governments (instead of ultimately bearing all of the liability, as they do now, of COVID-19), and would also incentivize private entities to take out insurance products to cover adaptation costs, given a full bailout was no longer a reliable assumption.

Theoretically, this could then create vast pools of capital, which (particularly if insurance accounting rules were changed) could be reinvested at the prevention end of the cycle. For example, the biggest barrier to investment in low-carbon energy is not the lack of capital which wants to invest sustainably, but the lack of appropriate vehicles — largely because most of the new investment which needs to take place is in emerging markets, which by their very nature are often sub-investment grade. At the same time, the $40 trillion and counting of ESG-screened assets under management (AUM) which wants to invest typically sits with developed market pension funds with a much lower risk tolerance. So, if this proposed government and insurance-funded vehicle could be further 'leveraged' by the addition of private capital, it would effectively create a ready-made pool of blended finance. This in turn could drive investment into prevention, thereby reducing the likelihood or severity of occurrence of these systemic crises, and subsequently reducing collective liabilities via the interlinkages of systemic risks. Essentially using the previously negative interlinkages of systemic risk as a force for good, by turning them against themselves.

Figure 25. Re-Routing Adaptation Insurance Premiums Into Prevention and Mitigation Measures



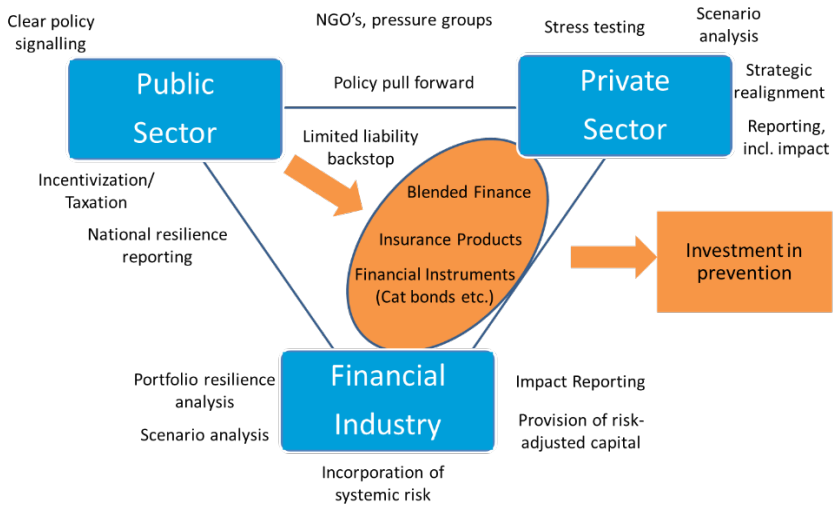
Source: Citi Global Insights

Mandated reporting of exposures and of resilience (insurance, prudential buffers, adaptation measures etc.) could also further incentivize systemically-responsible behavior, by directing private capital towards more resilient or responsible businesses, and away from activities which exacerbate systemic risks, via differentiated costs of capital (via perceived risk/return thresholds). Mandated sovereign reporting (on preparedness, impact, and resilience), perhaps along the lines of the 'Voluntary National Reviews' where countries report their performance against achievement of the UN SDGs, would also help to incentivize governments to signal and adopt systemically responsible policies, again via financial signals and the availability/cost of external financing.

Public policy has an important part to play here, by clearly signaling the direction of travel (e.g., on for example carbon markets/taxation and prices, or taxation on land use, deforestation etc.). This could help drive further capital into sustainable solutions, by effectively raising the cost of capital or return thresholds on 'unsustainable' or 'systemically irresponsible' investment. Effectively the 'pull-forward' effects akin to central bank interest rate policy signaling highlighted by Mark Carney. If done correctly, this could take the financial burden of these economic realignments out of the public sector and firmly into the private sector, thereby overcoming the barrier of political short-termism and cost highlighted earlier.

This all sounds simple on paper, but is fiendishly complex to achieve in practice. However, the challenges facing us from systemic risks are equally fiendish in their individual impact, let alone collectively via their interlinkages, and hence it is imperative that we try. It is clear that individually rational actions will also not provide a solution, indeed they may exacerbate the problems, and hence some form of collective and systemic solution is necessary. The above proposed approach to dealing with systemic risk, in terms of who does what, can be summarized in Figure 26 below.

Figure 26. Systemic Approaches for Addressing Systemic Risk



Source: Citi Global Insights

Some might look at this idea as a utopian daydream, feeling that ultimately we are all out for ourselves, and moreover, that the private sector will baulk at having the burden of this solution placed upon it (especially by the public sector). The reality however is that this is already the case. The extraordinary rise of ESG and the $40 trillion of AUM now being screened, alongside the rise of the TCFD and moves to mandatory climate exposure reporting in markets such as the U.K. and New Zealand with others sure to follow, reflects the attitudes of the ultimate asset owners, and shows that companies can no longer ignore these issues. If corporates want access to low-cost capital, they need to consider systemic risks and demonstrate their impact, their resilience, or their plans to become resilient. Moreover, organizations which are seen as causing or exacerbating systemic risk, such as for example coal, are rapidly seeing capital withdrawn, even before ever-ratcheting carbon prices make this a foregone conclusion. So to say the public sector is 'forcing' the private sector to do this is wishful thinking and ignores the changing attitudes in society. In many ways all we are really proposing is a formalization of the status quo.

From Adaption to Mitigation and Prevention

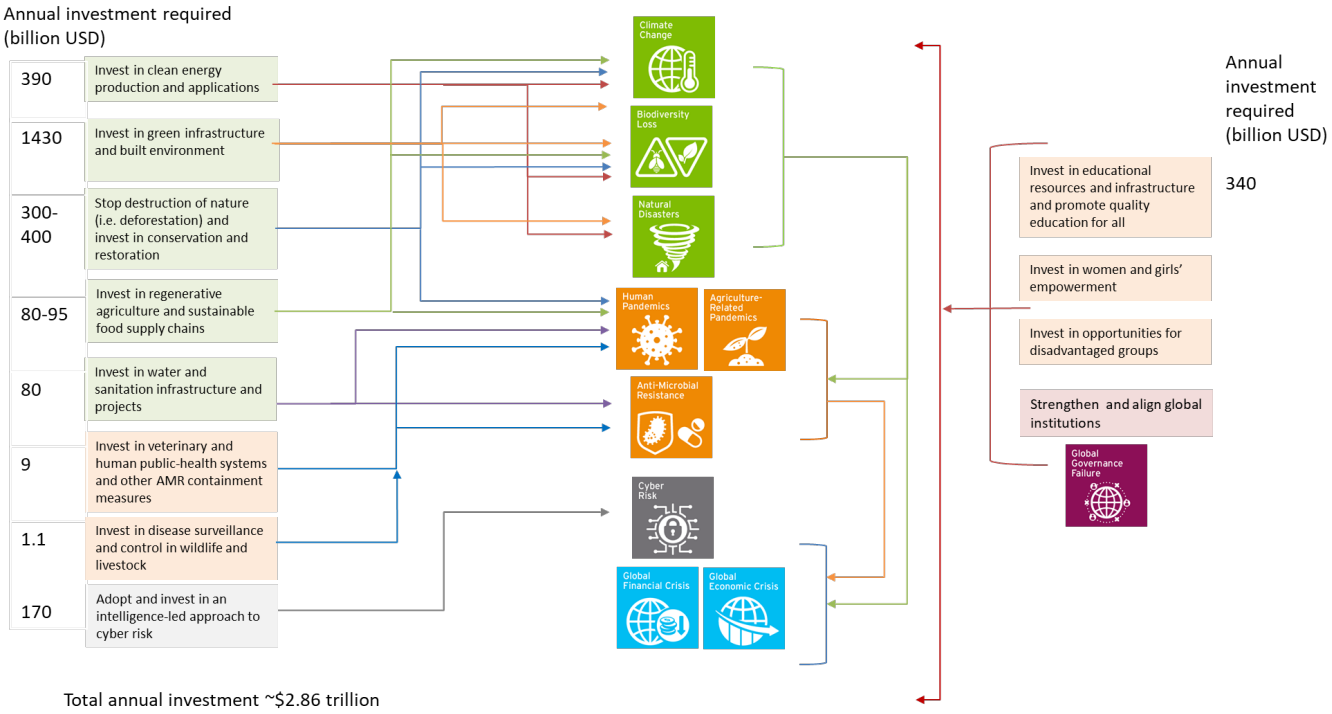
If focusing capital on prevention (or mitigation) seems to be the key, and there are potential solutions to creating a pool of capital, how do we know specifically where to direct that capital? A key theme of this report has been the interlinkage of systemic risks, and how the occurrence of one can increase the likelihood or severity of another. However, those feedback loops equally offer the potential to be turned into a positive, where 'solving' for one risk can actually reduce the impacts of, or indeed the probability of another from occurring. For example, investing in reducing deforestation can have a positive impact on climate change, but could also help to reduce biodiversity loss, as well as potentially reduce the risk of pandemics (via reduced zoonotic transmission). Therefore understanding the interlinkages between risks might allow us to focus on which individual solutions might have broader benefits which could ripple through the system.

Critical Pathways to Addressing Systemic Risks

The UN Sustainable Development Goals and systemic risks are intrinsically linked. There are now numerous reports and articles on how we can build back better and greener post-COVID-19, and many leaders, including António Guterres, emphasize the opportunity here to use the UN SDGs for COVID-19 recovery and to fast track their achievement.

If we consider what a sustainable future means — is it not inherently the elimination or reduction of, or adaptation to systemic risks like climate change and pandemics? Hence the UN SDGs are an extremely helpful framework but the actions needed are rather overwhelming. In our 2018 Citi GPS report on UN SDGs, we developed the systematic framework for aligning investments to the goals highlighted earlier (Citi GPS: United Nations Sustainable Development Goals). For this report on systemic risk, we have built on that approach and developed a critical pathway for managing the Global Risk Nexus, by choosing a set of solutions and investment opportunities we think can deliver multiple benefits across the risk nexus. These systemic risks may be amplified through their inter-connectivity but so too are the solutions which can deliver cascading benefits. Figure 27 below shows our identified solutions and their investment opportunities. This is of course not an exhaustive list of solutions/actions that are needed to address each systemic risk, but are what we believe to be "win-win" strategies across the Global Risk Nexus.

Figure 27. Proposed Areas for Investment Which Can Prevent or Mitigate Systemic Risks via Interconnectivity of Risks



Source: Citi Global Insights

Conserving nature, transitioning to sustainable agriculture, and investing in clean energy are vital to mitigating and managing several systemic risks including Climate Change, Pandemic Potential, and Biodiversity Loss, which in turn reduces the likelihood of cascading disasters like Financial Crisis and Global Recession. We should also factor in the positive feedback loop that comes from stable economies and financial systems to managing the other systemic risks. Figure 28 provides more detail on the solutions we have chosen. There are plenty of reports identifying what actions and investments are needed to address individual risks, but what we have tried to do with this exercise is to bring out and bring together the solutions that are cross-cutting and can deliver multiple and cascading benefits across the Global Risk Nexus.

Figure 28. Cross-Cutting Solutions to Tackle the Global Risk Nexus

Investment	Amount (US$ bn)	Investment opportunities	Source
Invest in clean energy, production and applications	390	- Investment needed to address UN SDG7: Affordable and Clean Energy - Investments in energy efficiency, renewables and nuclear, improving energy access and reducing pollution - Net investment figure partially offset by lower investment in fossil fuel supply and generation, and by lower operational and fuel costs	Citi GPS (2018) UN Sustainable Development Goals
Invest in green infrastructure	1,430	- Current infrastructure and build environment systems are unsustainable, and have a negative impact on nature - Investments are needed for nature-positive built environment design, urban utilities, connecting infrastructure - Opportunities to combine human engineered solutions with natural ecosystems (nature as infrastructure)	WEF (2020) The Future of Nature and Business
Stop destruction of nature (i.e. deforestation) and invest in conservation and restoration	300-400	- Investments needed to safeguard life in oceans (UN SDG 14) and on land (UN SDG 15) - Most of the investment needed is in emerging economies (lack of funding, as well as key areas of biodiversity hotspots) -Current funding comes primarily from public and philanthropic sources, opportunities for private finance and blended finance mechanisms	IUCN (2018) Safeguarding nature through finance
Invest in regenerative agriculture and sustainable food supply chains	80-95	- Key financing needed for productive and regenerative agriculture, diversifying protein supply, and reducing food loss and waste - Hidden costs of global food system (health, environment, and economic) add up to $12 trillion, compared to market value of global food system of $10 trillion	Food and Land Use Coalition (2019) Growing Better: Ten Critical Transitions to Transform Food and Land Use
Invest in water and sanitation infrastructure and projects	80	- Investment needed to address UN SDG 6: Clean Water and Sanitation - In emerging economies, investments are needed for new infrastructure to improve access to water and sanitation - Over 2 billion people do not have access to safely managed drinking water	Citi GPS (2018) UN Sustainable Development Goals
Invest in veterinary and human public-health systems and other AMR containment measures	9	- Key measure is building veterinary and human public health capacities in low and middle-income countries - Other measures include prevention and control programs, R&D of new antimicrobials, vaccines, and diagnostics - This will also help to reduce the risks of pandemics, improve food safety and security.	World Bank (2015) Drug-Resistant Infections: A Threat to Our Economic Future
Invest in disease surveillance and control in wildlife and livestock	1.1	- Key measures include early disease detection and control, monitoring of wildlife trade as well as programs that reduce disease spillover from wildlife and livestock - Current efforts are severely underfunded and our exposure to zoonotic diseases are greatly underreported	Dobson et al. (2020) Ecology and economics for pandemic prevention
Adopt and invest in an Intelligence-led approach to cyber risk	170	- Organizations need to move beyond a reactive defensive approach to cyber towards an intelligence-led risk management strategy - A new security market driven by cloud usage and software-as-a-service (SaaS) is emerging	Gartner (2018) Forecast Analysis, Information Security, Worldwide Citi GPS (2019) Managing Cyber Risk with Human Intelligence
Invest in educational resources and infrastructure	340	- Investment needed to address UN SDG 4: Quality Education - Finance needed to provide universal pre-primary, primary and secondary education - Before COVID-19, around 260 million children (or 1 in every 5) were out of school. - As a result of the pandemic, 20 million more secondary school girls may be out of school	Citi GPS (2018) UN Sustainable Development Goals Malala Fund (2020) Girls' education and COVID-19

Source: Citi Global Insights

It is estimated the COVID-19 crisis could cost the global economy a total of $26.8 trillion over the next five years[81] and as of end March 2021 over 2.8 million have unfortunately lost their lives.[82] A study from Princeton University stated an annual investment of around $22 to $31 billion could help mitigate against future pandemics, mainly by investing in the reduction of deforestation, monitoring of wildlife trade, ending the wild meat trade in China, and funding programs for early detection and control.[83] The cost is a fraction of the expense when compared to the potential economic loss from the COVID-19 pandemic and the suffering felt by many.

If we look at the costs of tackling other global systemic risks we also reach similar conclusions. In our Energy Darwinism II report, we estimated the net benefits of investing in clean energy and therefore reducing the impacts of climate change far outweighed the costs of not doing so. With regards to biodiversity, it is estimated that $44 trillion of global GDP is dependent on nature,[84] and yet we are losing biodiversity at a staggering rate. The WEF also reports that for every $1 spent on nature restoration, at least $9 of economic benefit can be expected. The annual global funding needed for nature conservation is estimated at $300 to $400 billion by the International Union for Conservation of Nature (IUCN), but only $52 billion is currently being invested which comes primarily from public and philanthropic sources. Opportunities exist for private investments to help close the funding gap, possibly through blended finance mechanisms where public entities can help reduce the risks. The $9 billion needed annually for antimicrobial resistance containment constitutes one of the "highest yield development investments available to countries today" according to the World Bank.[85] Investments made to tackle antimicrobial resistance can also help to reduce the risk of pandemics as well as improve food safety and security, and farmers' livelihoods.

Stopping deforestation and preserving tropical forests in particular can help to address multiple challenges. Studies have shown that stopping deforestation and conserving forests could cost-effectively remove 7 billion metric tons of CO_2 annually, more than eliminating all of the cars in the world.[86] Investing in forest protection measures will also help protect biodiversity (over 80 percent of the world's terrestrial biodiversity are found in forests[87]), regulate climate and water flows, reduce risks of zoonotic diseases, as well as protect livelihoods and drug discoveries. However, despite all these benefits, we still lost a football pitch of primary rainforest every 6 seconds in 2019.[88] The need to protect forest ecosystems is more important than ever as we try to address multiple systemic risks.

We have not allocated investment costs targeting women and girls' empowerment, reduced inequalities, and strengthening of global institutions as these are more policy and governance issues, but recognize that investments are also needed in these areas (See Citi GPS: The Case for Holistic Investment in Girls, Citi GPS: Closing The Racial Inequality Gaps, Citi GPS: Inequality and Prosperity in the Industrialized World, Citi GPS: Women in the Economy, Citi GPS: Women in the Economy II.)

[81] See Figure 10.
[82] The Johns Hopkins Coronavirus Resource Center.
[83] Dobson et al. (2020).
[84] World Economic Forum (WEF) (2020a).
[85] World Bank (2017).
[86] Griscom et al. (2017).
[87] International Union for Conservation of Nature (IUCN) (2021).
[88] Weisse and Dow Goldman (2020).

If we add up the annual investment needed for the identified solutions, it comes to almost $3 trillion. While that may seem a vast sum of money, in the context of the potential costs of inaction highlighted earlier in this report (see Figure 10), it pales into insignificance, and makes a strong argument that we can't afford not to act.

Harnessing Prevention to Stimulate Growth

Moreover, these actions can not only save us from catastrophic disasters, but can also stimulate economic growth.

- The WEF reports a new nature-based economy could generate up to $10.1 trillion in annual business opportunities and 395 million jobs by 2030. [89]
- Numerous studies demonstrate the economic benefits of investing in clean energy, with a recent report by the International Renewable Energy Agency (IRENA) stating that clean energy yields an economic return three to eight times higher than the investment.[90]
- A transition to a sustainable food system could generate a return 15 times the related investment, and create new business opportunities up to $4.5 trillion a year.[91]
- If we consider benefits across sectors, a recent analysis found the current effects of air pollution are so bad, that moving from fossil fuels to clean energy would pay for itself in healthcare savings and productivity gains, even without considering climate change.[92]
- The solutions to many of these risks require investment in infrastructure. In our previous Citi GPS report Infrastructure for Growth (See Citi GPS: Infrastructure For Growth) we found that if targeted and executed correctly, infrastructure investment can have on average a multiplier effect of 1.4x, with specifically-targeted projects yielding much higher multipliers.
- The R&D required to tackle many of these risks, not least human and agricultural pandemics, or antimicrobial resistance, or indeed against cyber risk, can create entirely new and exciting industries, generating employment and enormous economic value, before considering the value of avoided risk.

It is difficult to come up with one number for the potential economic benefits that can be delivered by investing in the identified solutions given the complexity of the interacting systems. However, we hope this exercise has helped to demonstrate the relatively small cost of action needed versus the potential cost of inaction as well as the tremendous economic opportunities which they present. If nothing else, we should see the $3 trillion postulated above, in conjunction with the economic growth effects which it could generate, against the $15 trillion of economic stimulus already provided against COVID-19, and the extraordinary economic damage in terms of lost GDP and worldwide recession which it has caused — and soberly remember this is just one of our systemic risks.

[89] World Economic Forum (WEF) (2020b).
[90] International Renewable Energy Agency (IRENA) (2020).
[91] Food and Land Use Coalition (2019).
[92] U.S. House Committee on Oversight and Reform (2020).

Conclusions

The world of risk is changing, and the major risks facing sovereigns, supranationals, corporates, and individuals are perhaps greater than ever before, having evolved into so-called 'systemic risks' by virtue of the ever-more interconnected nature of our modern world, which while an undoubted force for good, can also create a vicious cycle of magnifying feedback loops.

We have also learned that much as they might seem so, these risks are not unprecedented, and we can to an extent predict them, analyze them, and in many cases even prevent them. The use of taxonomies and analyzing the interconnections and feedback loops, as in this report, can help us to identify and classify these risks, which in combination with scenario analysis and stress testing, can enable us to quantify the scale of the risk, and the exposure of individual entities to it, both in economic and human terms.

These micro-level approaches enable us to assess risk, and essentially help us to adapt to it or deal with it, but do not provide solutions per se. To find solutions to systemic risks, we unsurprisingly have to look at systemic solutions. The first stage in developing these solutions is to understand what the barriers are which are holding us back from dealing with the risk, such as their scale and complexity, the tragedy of the commons, the lack of appropriate insurance products, and systemic governance failures.

There is light at the end of tunnel though, and this is provided by the fact the very feedback loops which create systemic risk, can be used as a tool to leverage investment to actually prevent those risks occurring in the first place. With the correct policy signals from government and the provision of strictly limited backstops, we can create a functioning insurance market for systemic risks, which has the potential to create vast pools of capital, in addition to for example the $11.4 trillion of capital which currently exists in the European insurance industry alone. If we then combine that with the $40 trillion and counting of ESG-screened assets which want to invest sustainably, we have the capital to address many of the solutions proposed in this report. Moreover, it creates a ready-made version of blended finance, which can itself overcome many of the barriers to investment in emerging markets, which is so often where that capital needs to be deployed for maximum efficacy against systemic risk.

COVID-19 isn't an existential crisis, and is one we will overcome. Perhaps one positive which may come from it is it will focus our attention on the extraordinary magnitude of systemic risks, and that when the chips are down, we do have the ability to come up with vast sums of capital ($15 trillion and counting) which in the normal course of business we say we couldn't possibly afford. In hindsight, how much easier might it have been to find a few tens or even hundreds of billions of investment to prevent it occurring in the first place? Would we have argued collectively about who should have put how much in, if the choice was to each spend multiples of that investment in adaptation? If we extrapolate this chain of thought onto the vast liabilities which could result from climate change or biodiversity loss — each close to $50 trillion alone, let alone in combination — then the $3 trillion of investment opportunities to prevent and mitigate the occurrence of systemic risk seems like the sort of bargain which we might repent missing at our leisure – especially as for many of these risks there are defined tipping points beyond which we will not be able to reverse the effects. For example earlier this year, scientists found that a massive ice sheet in Antarctica known as the "doomsday glacier" is melting faster than previously believed, which has huge implications for global sea level rises.

If this argument in itself was not compelling enough, many of the prevention and mitigation measures have the ability to drive economic growth, with significant multiplier effects of up to 15 times, as described earlier. These would be attractive against any economic backdrop, but against the current global economic malaise of secular stagnation and ultra-low returns across all asset classes, it is surely an opportunity too compelling to pass up.

We know the next waves are coming and they will be bigger, closer together, and more costly. So let us take the lessons and opportunities from COVID-19, and harness the vast pools of capital which are out there and want to invest sustainably, and put them to work in prevention and mitigation rather than purely in self-interested adaptation, to prevent these risks occurring in the first place. The opportunity to offset hundreds of trillions of liabilities, for the sake of $3 trillion investment per year — a fraction of the capital available — which could also drive economic growth in a world of ultra-low returns and stalled growth, seems almost too good to be true. We must not let future generations look back and wonder what on earth we were thinking when we decided to take the risk.

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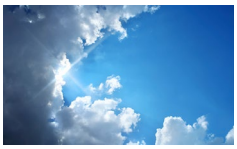

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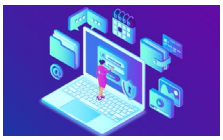

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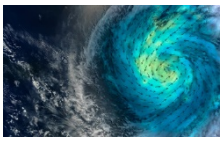

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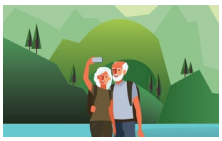

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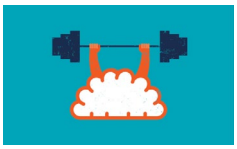
Car of the Future v4.0 – 2020 Update
The Race for the Future of Networked Mobility
January 2020

The Global Art Market
Drivers of Evolution

December 2019



Education: Power to the People
Exploring Opportunities for Private Capital in Education
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Digitizing Governments
The Journey to Enacting a Digital Agenda
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Electric Aircraft
Flightpath of the Future of Air Travel
September 2019

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For Better Or Worse, Has Globalization Peaked?
Understanding Global Integration
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Flexible, Digitized, and Sustainable
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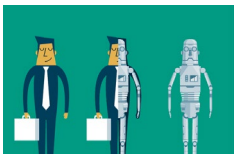

Technology at Work v4.0
Navigating the Future of Work
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Video Games: Cloud Invaders
Bracing for the Netflix-ization of Gaming
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Managing Cyber Risk with Human Intelligence
A Practical Approach
May 2019

Bank X
The New New Banks
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January 2019

Investment Themes in 2019
January 2019

Car of the Future 4.0
The Race for the Future of Networked Mobility
January 2019

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Key Insights regarding the future of Systemic Risks

SUSTAINABILITY

Forests are home to 80 percent of the world's terrestrial biodiversity. However, forests are disappearing at an alarming rate, which affects wildlife, ecosystems, livelihoods, and climate. / Stopping deforestation and conserving forests will help protect biodiversity, regulate climate and water flows, reduce risks of zoonotic diseases, as well as protect livelihoods and drug discoveries.

EDUCATION

Globally, over 1.5 billion people are classified as unemployed or in vulnerable employment. In times of economic crisis, this group is most immediately at risk. / Finance is needed to provide educational infrastructure from pre-primary through secondary education as well as job training.

INFRASTRUCTURE

Climate change is impacting surface temperatures and increasing extreme weather putting an increasing amount of the global population at risk of extreme heat and natural disasters. / Infrastructure investments are needed in for nature-positive built environmental design, urban utilities, and connecting infrastructure as well as infrastructure to improve access to water and sanitation.