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robust decisions in uncertain times

WORKING PAPER 2023/1

Global Drivers of Change

Horizon scan 2023

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23 January 2023

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1. Introduction

Although we constantly stress that the future is unknowable and that many possible outcomes are possible, nonetheless we CAN identify several broad themes or "megatrends" that will have an impact in most potential futures. We call these "Drivers of Change". The exact speed of development of each driver may vary but it is generally helpful to begin a foresight project with consideration of the implications of these drivers for the topic in hand. The drivers will themselves interact in complex and unpredictable ways, so it is best to be flexible in the analysis.

SAMI first put together a set of 12 Drivers of Change back in April 2018. Since then we consolidated these into a broader set of 6 and have continued to monitor emerging events and track them against this set of 6 major drivers of change. Many events simply reinforce or confirm our previous view, but some may indicate an acceleration or deceleration of the trend.

This Working Paper was finalised on 23rd January 2023 – later developments will be covered in future revisions.

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2. Population Dynamics

DEMOGRAPHICS

Since the publication of *Empty Planet: The Shock of Global Population Decline* in 2019 and the population forecasts by the *Institute of Health Metrics and Evaluation (IHME)* at the University of Washington in 2020, we have been flagging the change in base case assumptions about population growth. IHME forecast **global population to peak in 2064** at around 9.7 billion people and fall to 8.8 billion by the end of the century. Other forecasts are even lower.

IHME concluded that:

- By 2100, **projected fertility rates** in 183 of 195 countries will not be high enough to maintain current populations without liberal immigration policies.
- 23 countries. including Japan, Thailand, Italy, and Spain, will see their **populations shrink by more than 50%** by the end of the century.
- Dramatic declines in working age-populations are predicted in countries such as **India and China**, which will hamper economic growth and lead to shifts in geo-political dynamics.

The widespread and sustained declines in fertility are due to improvements in access to modern contraception, and the education of girls and women. In the West, there is a feeling that some young people are put off having children because of the state of the world. And it is unclear how much an impact declining sperm counts caused by micro-plastic pollution may be having.

Fertility rates in Italy and Spain will be at 1.2; even Nigeria will see rates fall from 4.6 births per woman in 2017 to just 1.7 by 2100.

Europe is the continent with the lowest total fertility rate: *1.50 births per woman* in the EU in 2020, well below the replacement rate.

China's population is has fallen for the first time in 60 years, with the national birth rate with a fertility rate as low as 1.17. India's fertility rate in 2021 was 2.1 (replacement rate) and *India surpasses China* around about now. However, its population is also projected to drop before the end of the century.

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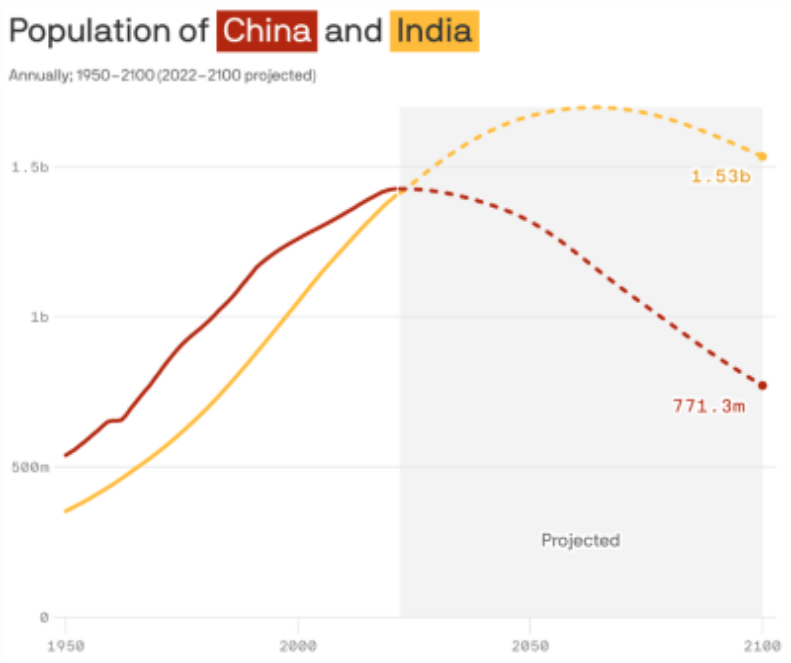

GRAPHIC BY AXIOS WITH DATA FROM UN

Ageing

An obvious consequence of this pattern is an ageing population. IHME suggest that as fertility falls and life expectancy increases worldwide, the number of children under 5 years old is forecast to decline, whilst the number of individuals older than 80 years is projected to increase six-fold, more than double the number of under-5's.

Furthermore, the global ratio of non-working adults to workers was around 0.8 in 2017, but is projected to increase to 1.16 in 2100 if labour force participation by age and sex does not change.

In England and Wales, *2021 Census figures* show that over one-sixth (18.6%, 11.1 million) of the population in 2021 were aged 65 years and over, up from 16.4% in 2011.

Inevitably, this brings challenges in funding care for the elderly, particularly the increasingly infirm, and those with dementia.

Demographic dividend

Some countries, however, may be fortunate to experience a *"demographic dividend"*, where the working population has a lower proportion of young dependents. This leads to larger investments per child, more freedom for women to enter the formal workforce and more household savings for old age.

*Latin American c*ountries were thought to have had a demographic dividend during to 2000's, but the window of opportunity seems to be passing. Tanzania has the number of dependents per 100 in working age falling from 96 in 2015 to 60 by 2100. Seizing the opportunity of a demographic dividend requires simultaneous investments in decent job creation, good governance, infrastructure and a functioning business climate.

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Policy reactions

Governments in several countries are attempting to turn the tide of falling fertility rates.

- Hungary: introducing nationalised IVF clinics; "*baby-expecting loans*", written off if a couple have 3 or more children.
- Italy and Greece have introduced "baby bonuses".
- China: having eliminated its one or two children policy, *China is encouraging companies to give incentives for child-bearing;* but has yet to see a positive reaction from young women.
- Russia offers bonuses for two or more children. In January 2020, president Vladimir Putin suggested extending the *maternity capital program* in the country to include births of first children. Furthermore, the program's financing was planned to rise each year.
- In Russia, a law passed in December made discussing a *childfree lifestyle* and homosexuality in public illegal because it is as harmful as extremism and drug use. Draft legislation introduced to parliament alleged that "new values" were undermining Russian society and exacerbating the demographic crisis.
- Anti-abortion practices are on the increase: in *Poland,* and in Republican states in USA following the overturning of Roe v Wade.
- Overturning Roe v Wade could threaten the court's 1965 ruling in *Griswold v. Connecticut,* which established the right to privacy and legalized birth control since it was based on similar legal grounds. Some Republicans have already expressed opposition to Griswold, suggesting that precedent could be challenged in court next.
- Addressing the increasing population of elderly and infirm, we may begin to see a rise in assisted dying policies.

MIGRATION

Continued conflicts around the world, and increasing challenges from climate change will inevitably drive increased migration. Nearly *90 million people* were forcibly displaced in 2021, compared with 40 million in 2011. 53 million of these were displaced internally. More than two thirds (68 per cent) of all refugees displaced abroad came from just five countries – Syria, Venezuela, Afghanistan, South Sudan and Myanmar. Turkey hosted nearly 3.8 million refugees, the largest population worldwide.

In addition to these forced migrations, the appeal of economic migration increases. A survey of 18-24 year olds in Africa showed dissatisfaction with their countries: *52% planned to move abroad* in the next three years, with the number increasing to three-quarters in Nigeria and Sudan.

In recent years there has been resistance to immigration in the West. Most startlingly, the far-right Sweden Democrats now form part of a coalition government, their participation determined by a coalition agreement on far tighter immigration. The demographic challenges described above however could be changing perceptions. Labour shortages in the UK have already led to industry groups asking Government to relax quotas. Might we soon see competition for young and healthy immigrants to provide dynamism to ageing economies?

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URBANISATION

The number of *Africans living in urban areas* keeps increasing and it is expected that by 2050 the number will exceed 950 million. While this urbanization brings opportunities, it is also and above all a source of real challenges, particularly for intermediate cities which will be affected by two thirds of this growth.

In 2018, *55% of world's population lived in urban areas*, up from 30% in 1950. By 2030 this will grow to 60%. Northern America was the most urbanized region in the world, with 82 per cent of its population living in urban areas.

Between 2018 and 2050, the urban population of Africa is projected to triple and that of Asia to increase by 61 per cent, so that by 2050 most of the world's urban population will be concentrated in Asia (52%) and Africa (21%).

END THOUGHTS

Demographics is one of the more predictable drivers of change, yet even here we are seeing radical departures from previous orthodoxy. The size and structure of countries' populations has implications for so many other aspects of their global position, economic strength and even military power, particularly for those whose populations are shrinking. Conversely, those countries in Africa with growing number of young males could be vulnerable to increasing conflict. The interaction with social attitudes – open or restrictive – is a choice each country must make.

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3. Geopolitics

Our second global driver of change has, for a long time, been Geo-politics. In our definition this includes a move towards a "polynodal world" – changing balances of global power dynamics – and relative economic growth and inequality.

This view is based on the perception that the post cold-war "Washington consensus" is falling away. The geo-political dominance of the US has declined, with the Trump presidency in particular moving away from taking a global lead, and we are now seeing a much more multi-polar or polynodal world. Populism has led several developed countries to focus internally, leaving a space on the global stage for others to fill. The demographic trends we discussed earlier reinforced this perception.

In 2022 of course we saw geo-politics burst into the foreground, with both Russia and China becoming more aggressive. Other regional powers may also begin to emerge; and the way smaller countries navigate between the power blocs will be increasingly varied.

RUSSIA

Russia's invasion of Ukraine has highlighted these dynamics. On the one hand this has led to greater co-operation and consensus in the West, with Sweden and Finland renouncing their traditional neutrality and applying to join NATO. Concerns abound that Russia may be seeking to extend its influence back to a "Greater Russia" model, risking confrontation and a new cold war.

But outside of the West, the situation is often viewed differently. *India has refused to condemn Moscow a*nd join Western-led sanctions. Each of the other major powers—the United States, Russia, and China—are looking to keep India onboard. India could carve out an independent superpower role, hasten the transition to a multipolar international system, and even gain a permanent United Nations Security Council seat.

African countries see things differently as well. The lack of Ukrainian grain supplies and higher prices could be disastrous, especially as many countries are suffering from droughts. Western aid is being diverted to Ukraine, further exacerbating the problem. Russia launched a charm offensive. Mostly, African countries just want the war to stop.

Climate change will also affect Russia's global position. Melting ice caps means ships can use the Arctic shortcut, taking two weeks off a voyage from Shanghai to Rotterdam compared with existing routes. The Northern Sea Route, which extends from the Kara Sea to the Bering Strait, is under Russian control. A report, *The Next Front? Sino-Russian expansionism in the Arctic and a UK response*, suggests that President Putin is about to pass a law that requires Russian pilotage of vessels seeking to use the Northern Sea Route. Russia is re-opening *50 Soviet-era military posts in the Arctic.*

CHINA

China's long-term future is also inherently uncertain. On the one hand its military, political and economic expansionism demonstrate President XI's will to extend its influence, even dominance. On the other, the economic tensions arising from the imminent demographic shift and rumours of internal political unrest suggest that instability could be around the corner. The Sino-Russian relationship is a constant delicate dance, seemingly having cooled during the year.

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On the ***military*** side:

- China's attitude to *Taiwan* US analysts fear that Taiwan could not be defended against a direct attack.
- NATO's 2022 *"Strategic Concept"* report identifies China as a "systemic challenge" and determines to "protect against the PRC's coercive tactics";
- China's intimidation of countries around the South China Sea continues, *including militarising artificial islands.*
- China has signed a security pact with the *Solomon Islands* and is wooing several other Pacific islands. This could enable it to position naval assets in the region undermining US and Australian positions.
- To India's chagrin, China exploited Sri Lanka's weak economic position to force it to allow a "*spy ship*" to dock there.

Economically:

- The *Belt and Road Initiative:* this global infrastructure development strategy adopted by the Chinese Government in 2013 is a way of projecting economic power. As of March 2022, 146 countries were listed as having signed up to the BRI. Examples of BRI investments include ports, skyscrapers, railroads, roads, bridges, airports, dams, coal-fired power stations, and railway tunnels.
- The BRI has been criticised as neo-colonialism and debt trap diplomacy. Beijing pressured Tajikistan to handover 1,158 km^2 territory, for wiping off about half its debt. Other nations with a similar risk are Pakistan, Madagascar, Mongolia, Maldives, Kyrgyzstan, Montenegro, Sri Lanka, and Laos all of which have borrowed large sums from China. Some academics however describe these concerns as "overblown".
- China *waived debt* for 17 African countries to argue against western bullying.

On the other hand:

- The Chinese *economy is under pressure.* Official figures show the gross domestic product (GDP) of the world's second largest economy rose 3% in 2022, well below the government's target of 5.5%.
- Covid lockdowns and demographics also impacted. In July 2022, China had its *weakest quarterly growth in 2 years,* as COVID-19 lockdowns in major cities hit production. The implications of the recent rapid ending of Covid controls are presently uncertain. The policy had a major impact on the country's economic activity.
- *China will get old before it gets rich*, slowing the economy as revenues drop and government debt increases due to soaring health and welfare costs. will have to adjust its social, economic, defence and foreign policies.

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- The *costs of being a superpower* are already seemingly causing concern, and spending on the Belt and Road Initiative has been falling since 2017.

- The Chinese *property market* is in difficulty: property sales could fall by one-third this year, as people lose faith in the market and pressure increases on struggling developers to complete presold apartments.

- *Huawei* suggested that "the next decade will be a very painful historical period, as the global economy continues to decline".

Internal ***politics*** are a challenge too:

- The demographic pressures of an ageing population will bring economic and political challenges.
- The unity of the Chinese Communist Party may itself start to fracture as President Xi is said to be *facing widespread opposition within the* party.
- Discontent has been building for a while. There has been a succession of highly unusual leaks from the Chinese elite all seemingly designed to stress President Xi's direct responsibility for the country's problems.

We could easily create several very contrasting scenarios of China's future.

AFRICA

As the one region not facing population decline by the end of the century, Africa has an opportunity to exploit that growth and build on a "demographic dividend".

Nigeria's working-age population is forecast to grow over the course of the century (from 86 million in 2017 to 458 million in 2100). Its economy will grow rapidly and it could rise to be have the 9th largest GDP by 2100.

In *Tanzania,* the number of dependents per 100 people of working age is projected to fall from 98 to 60, opening up prospects of economic growth.

The African Development Bank's *African Economic Outlook m*akes it clear that the pandemic and Russia-Ukraine war could leave a lasting impression over several years. GDP growth of 6.9% in 2021 is forecast to slip to 4.1% in 2022 and remain at that level in 2023. Climate change is seen as the most existential challenge to Africa's development today.

The Covid pandemic could have even more disruptive effects. Studies suggest that disease outbreaks may initially suppress *social disturbances*, by limiting contact, but encourage it in the longer term.

SUPPLY CHAINS

The recent shocks to the economic system from the pandemic and war have exposed the fragility of globalised supply chains, whether in grain, fuel or semi-conductors. Security of supply has leapt up the list of concerns for companies and countries alike. The benefits of "Just in time" sourcing are beginning to be outweighed by the risks. Ultimately the more

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cautious approach adopted will prove a drag on growth globally, though there will be local opportunities emerging.

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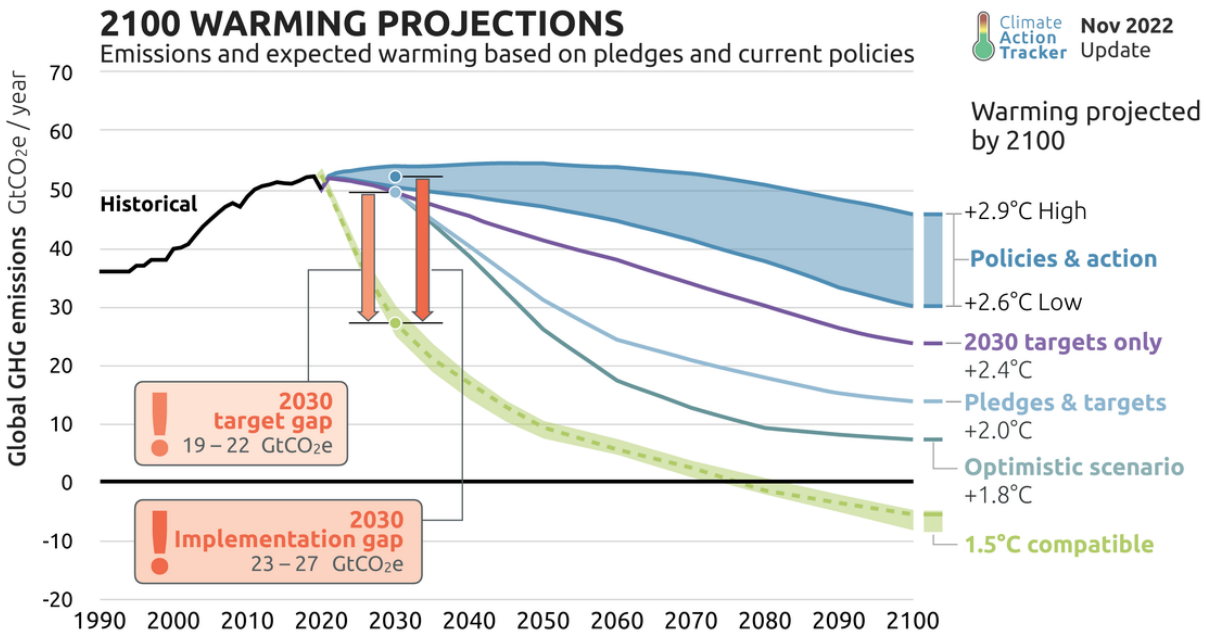
4. The climate crisis

COP27

COP27 did little to move the world towards lower carbon emissions. Keeping the increase in global temperature to ***1.5˚C now seems to be an unlikely outcome***, with 2˚C to 2.5˚C looking far more probable and worse still possible. COP26 chairman Alok Sharma described the outcome as "1.5˚C on life support"; António Guterres, secretary general of the UN, warned: "Our planet is still in the emergency room".

Climate Action Tracker's most recent projections suggest 1.8˚C as the "optimistic" scenario.



GRAPHIC BY CLIMATE ACTION TRACKER, NOVEMBER 2022

At Cop26 in Glasgow in 2021, countries agreed to return each year to strengthen their carbon emission commitments, a process known as the ratchet. At Cop27, some countries tried to renege on the 1.5˚C goal, and to abolish the ratchet. A resolution to cause emissions to peak by 2025 was taken out.

The one achievement of COP27 was the establishment of the principle of a ***"Loss and Damage"*** fund to help developing countries deal with the impacts of climate change. However, none of the developed countries committed to a specific sum of money for this fund, and that will be subject to continued negotiations. Some research suggests that by 2030, climate-related losses could reach *$580bn per year.* There was nothing in the UK Chancellor's "Autumn Statement" to contribute to that. An innovation here was to look to the private sector to contribute, either voluntarily or more likely through various levies on polluting industries.

CLIMATE CHANGE IS HAPPENING:

- The *floods in Pakistan* affected 33 million people, one in 7 of the population; they killed over 1,600 people and 800,000 livestock.

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- The *summer heatwaves in Europe*, caused evacuations and heat-related deaths. The highest temperature recorded was 47.0 °C in Portugal; temperatures exceeded 40°C in the UK for the first time.
- According the UN, *drought frequency* and duration has increased by nearly a third since 2000.
- Irreversible *declines in freshwater* storage are projected in parts of Asia by 2060
- The average temperature in the UK during 2022 was the *highest ever at over 10˚C*.
- Record-high winter temperatures affected much of Europe over the new year; Budapest reached 18.9˚C, Bilbao 25.1C , and ski resorts in the northern Spanish and the Alps closed for lack of snow.

Tipping points – positive feedback loops potentially starting irreversible runaway growth – add complexity to the analysis. *Research published* in the journal Science suggests that 5 tipping points may have been reached at the current state of global warming of 1.1°C.

These include the collapse of the Greenland and West Antarctic ice shelves, tropical coral reef die-off, Northern permafrost abrupt thaw, and collapse of the Labrador Sea current. A further 8 tipping points are at risk with temperature rise in the range of 1.5°C to 2°C.

The *Amazon rainforest* is emitting more carbon than it is absorbing, with deforestation creating a vicious circle, increasing average temperatures. Less forest means less recycled rain, less vapour to cool the air, less of a canopy to shield against sunlight.

PROGRESS

Progress to meet Net-Zero commitments has been mixed, at best. On the plus side:

- The US Government was successful in passing its "*Inflation Reduction Act*" that authorises $369 billion spending on energy and climate change and brings the U.S. significantly closer to the goal of reducing greenhouse gas emissions to 50% below 2005 levels by 2030.
- *China* has consistently over-performed on its renewable energy targets.
- In *Australia* – previously a laggard due to its coal industry – the new Government voted to make emissions reduction a key national energy goal, in a major step forward in the clean energy transition.
- In the UK, the High Court said the *government's net-zero strategy*, which sets out plans to decarbonise the economy, is in breach of the law, because it doesn't explain how targets will be met. We mark this as a positive because setting targets is of no use if there are no paths to get there.

However, others are lagging behind:

- *India* missed its renewable energy target for 2021 and 2022
- No new, more ambitious *2030 climate targets* have been announced and participation in sectoral initiatives has stalled since COP26 in Glasgow. This goes against the clear agreement of the Glasgow Pact to update national 2030 climate targets in 2022.
- *Climate Action Tracker* calls Russia and South Korea's polices "highly insufficient," and Iran comes in as "critically insufficient."

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UKRAINE

The Russian invasion of Ukraine complicates things further. On the one hand the massive increase in oil and gas prices means we are seeing urgent plans to reduce energy consumption by both *governments* and individual *households*. A push towards greater use of renewables would seem to be an obvious response. However, politicians are leaning towards older approaches, to approving *fracking* and more *oilfield development*, which because of their 10-year development horizons will build in carbon emissions for many years to come.

BIODIVERSITY

Biodiversity is falling dramatically and whole eco-systems are collapsing. The accelerating loss of species around the globe is now referred to as the *sixth mass extinction*. The latest *UN Biodiversity Conference, COP15*, gained commitment to *"30 by 30"* – protecting 30% of the planet by 2030 – in a deal hailed by some as equivalent the step forward on climate at the Paris conference of 2015. As with climate issues, however, the issue of who pays remains unresolved. Other concerns include that a goal to reduce the rate of species extinction tenfold by 2050 represents less ambition than was agreed by the UN 10 years ago, and the deal is weak on ensuring accountability.

TECHNOLOGY

Technology can help. *Solar* is the cheapest form of energy in most places. Advances in *battery technology* are leading to ways of smoothing out the intermittent nature of wind and solar power generation. Hydrogen (especially wind-turbine powered hydrogen) is increasingly seen as a way forward with *new gigafactories*, an *EU strategy*, *German support* and experiments in *Formula 1*.

A second area of technology development is *longer duration energy storage*, ways of compensating for days when solar and wind power are not available. Examples include includes flow batteries, mechanical devices (such as pumped hydro, liquid air and compressed air), thermal storage and hydrogen.

FINANCIAL IMPACTS

In over 2˚C cases, more extreme weather events, droughts, fires, floods, storms will lead to:

- Migration increasing, with massive economic dislocation: nearly *10% of the population of Bangladesh* are expected to have left the country by 2050; by 2020 1.7 million people in the US were displaced by extreme conditions, fire, storms and flooding; *globally, over one billion people* are at threat of being displaced by 2050.
- Increased insurance claims with some properties uninsurable
- The abandonment of some areas – not just in Africa, but along rivers and coastlines (the Welsh village of *Fairbourne* is already due to be wiped off the map)
- Funding "Loss and Damage" – governments, taxing carbon emissions from certain industries – the potential for demands on this fund to escalate dramatically is huge.

But even the most optimistic scenarios have financial implications.

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If Net Zero policies are implemented fully, there are serious impacts on the fossil fuel industry. The International Energy Agency's "pathway" to net-zero implies fossil fuel resources become stranded assets. Seven top firms downgraded their assets by $87bn in 9 months and reduced payments to shareholders. BP reckon 2020 was "peak oil". Burning the world's proven reserves of fossil fuels would emit 3.5tn tons of greenhouse gas emissions, more than have occurred since the industrial revolution, easily exceeding that limits needed to keep warming to 1.5°C.

The National Grid will require re-engineering to manage more decentralised energy production and the needs of electric vehicles.

On the other hand, insulating homes in Britain and installing heat pumps could benefit the economy by £7bn a year.

PUBLIC OPINION

Over the years since we first included climate change in our Drivers of Change, the issues have become more and more central to public debate. In March this year, 85% of the UK population were fairly or very concerned about climate change. Outright climate change denial is now rare.

We are seeing some positive signs of behaviour change, but more will be needed. 73% of people in the UK believe the climate is changing as a result of human activity. While many are prepared to move to electric vehicles, the appeal of heat pumps and veganism is much less.

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5. The 4th Industrial Revolution

We identified the "Fourth Industrial Revolution" – the application of digital technologies and related advances – as our fourth Driver of Change. The Covid-19 pandemic led to the broader adoption of **digital technology to everyday life.** Working from Home meant changing work patterns, with implications for transport systems, the built environment and building design, and the role of physical shopping. The (at least partial) separation of workplace and office meant that rural areas became more attractive. *Digital health technology* could support telehealth visits, to better meet both patient and provider needs. In most cases, hybrid solutions seem to be the "new normal". "Digital twins" are finding applications in construction, where a 3D scan of the building is used to test performance.

A major shift is occurring at the nexus of the Internet of Things (IoT) and Artificial Intelligence. **INTERNET OF THINGS** means a massive increase in sensors, many embedded in other devices, or even in the body, generating vast amounts of data. For example, engineers have devised a new kind of wearable sensor – *"e-skin"* – that communicates wirelessly without requiring onboard chips or batteries. But *digital health tools* are in practice delivering the most for wealthy, well-educated patients, who can afford to buy the gadgets and the accompanying services. According to surveys, digital health currently helps those who have the best access to healthcare in all other channels as well.

Romania's first *'smart' forest* has been equipped with acoustic monitoring sensors and AI technology to identify the sounds of chainsaws being used and send real-time alerts to rangers' mobile phones in order to prevent illegal logging.

ARTIFICIAL INTELLIGENCE is becoming increasingly prevalent. The term is sometimes hyped simply to mean algorithmic decision-making, but sophisticated AI is emerging in everything from personal assistants to high-end medical applications. Here it is *surpassing radiographers, diagnosing skin cancers*, and *detecting sepsis*. Mostly these applications are used to support existing professionals rather than replace them.

The debate about whether AI will cause mass redundancies is ongoing. There is a school of thought that suggests that human empathy will ensure many roles remain, despite AI being better at *recognising facial expressions* than humans. Nonetheless, most commentators suggest that AI will create more jobs than it destroys.

One step forward that created a lot of interest is *ChatGPT*, an AI-assisted chatbot that can generate fluent prose, and its graphic counterparts including Dall-E. Despite major concerns about jobs under threat, the best assessment of its future role is as an assistant, a tool that augments human capabilities, that has applications in almost every field. The possibility of convincing "deep fakes" has serious implications for personal privacy, impersonation and fraud.

AI is also having to face up to ethical issues. Because of the data AI systems are trained on, existing bias can be built into the system. Skin cancer applications work less well on dark skin; face recognition systems perform less well with ethnic minorities. UNESCO has agreed on *common values and principles* needed to ensure the necessary legal infrastructure to ensure the ethical development. These principles also explicitly ban the use of AI systems for social scoring and mass surveillance, though this has not prevented some countries extensively using AI systems for exactly that. And in the 2021 *Reith Lectures*, Professor

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Stuart Russell Professor, founder of the Center for Human-Compatible Artificial Intelligence at the University of California, Berkeley, describes the progress in restricting "Lethal Automated Weapons Systems". We wrote in more depth about AI in our blog on the *"Industry 4.0: Enabling Technologies and Inclusive Digitization for Post COVID-19 Economic Recovery in APEC Value Chains"* conference.

AUTONOMOUS VEHICLES

The dream of fully "self-driving cars" (*"Level 5"* in the industry jargon) is probably some way from being realised, as the challenges at the extremes, in the last 10% of experiences, are very hard to address. *Elon Musk* has promised self-driving cars "Next Year" every year since 2014. *Ford and Volkswagen* have closed their self-driving operation.

However, advances at *"Level 4"* (self-driving in limited areas) are emerging:

- *Mercedes* have been granted a licence for an automated valet parking system
- *Japan* decided in December to allow highly autonomous "level-4" self-driving vehicles to be used for transit and delivery services from April 2023
- In June 2022, *California regulators* gave a robotic taxi service the green light to begin charging passengers for driverless rides in in less congested parts of San Francisco from 10pm to 6am.
- *Baidu* has increased the operating hours at night of its driverless taxi service in Wuhan, central China. From this week, the public will be able to use its robotaxis in Wuhan between 7 am and 11 pm without safety drivers in the drivers' seats.

The UK Government is preparing the ground with regulations that make *manufacturers responsible* for the vehicle's actions when self-driving.

Truly autonomous vehicles would lead to major changes in road design, parking and car ownership. It is often assumed that AVs would go hand-in-hand with car sharing. But surely if an AV is in effect a moving living room or office, personalisation would be essential?

IBM's crewless *AI-powered Mayflower ship* broke down on its second attempt to cross the Atlantic ocean alone. The problem appears to with the ship's generator, and none of its machine-learning software capabilities have been affected.

Airplane auto-pilot systems are as near as any to a fully autonomous vehicle. Volkswagen has demonstrated *a prototype flying autonomous taxi.*

ROBOTS

Humanoid robots attract attention, but the practical developments are generally very different. Most perform a limited range of tasks – vacuuming, mowing the lawn – with defined characteristics. *"Cobots"* are increasingly used to collaborate with each other and with people, merging the robots' strength and precision with the adaptability and situational awareness of human users.

In four experiments on pig tissues, a *robot sutured* two ends of intestine—one of the most intricate and delicate tasks in abdominal surgery – without human help. The procedure requires a high level of repetitive motion and precision, with high accuracy and consistency.

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Soft robots with natural movements and tactile responses like those of living organisms can apply the right amount of force to grip different objects. They could be suitable for exploring rough and unknown terrain or for medical applications.

DRONES

Drone applications are multiplying rapidly, as cheaper versions become available – from *surveillance* to *delivering medicines* in difficult terrain. Military applications use *drone swarms* that communicate with each other to overwhelm defences.

They are also getting smaller. A team at MIT have developed *tiny drones* that can fly, dodge, and weave like actual insects. The drone's wings flap nearly 500 times per second, 50 times faster than a typical hummingbird.

3D PRINTING

3D printing is increasingly viable at scale, even up to *printing a house* in just 12 hours. A hybrid design that combines *3D-printed concrete* with conventional wood framing shows how each material can be used where it works best.

A novel combination of a team of *drones equipped with 3D printers* is being used to print emergency shelters in disaster zones.

Extensive use of 3D printing could have important secondary effects. If products can be printed locally there will be less need for road haulage. Value will migrate to the intellectual property in product design rather than in manufacture. But there may be quality control and safety issues – will people be happy with brake linings printed in a back-street garage?

VIRTUAL REALITY (VR)

Virtual Reality (VR) technology applications appear to be moving into specific niches, mainly around education and training. *One example* is enabling surgeons to plan and prepare for heart surgery using a 3D digital image of the patient's heart. This can shorten operation times, reduce the need for multiple surgeries and lead to better outcomes and experiences for patients.

MACHINE INTERFACES

Advances in *brain-reading devices* enable users to control a robotic arm, use Photoshop software, play 'shoot-'em-up' video games, and now to drive a simulated car through a virtual environment, changing speed, steering and reacting to hazards. Are these the first steps to "telepathy"? The challenges faced by *Neuralink* imply that, absent a sudden breakthrough, full machine/brain interfaces may be a way off.

BEYOND 4IR

There's a good argument that we are already in the Fourth Industrial Revolution. As futurists, therefore, we're already thinking about:

INDUSTRY 5.0 is described as *"people working alongside robots and smart machines", and includes* AI, Connectivity, Robotics and the development of such innovations as "Smart Cities". Industry 5.0 is more human-centric than the process-driven 4.0.

INDUSTRY 6.0 evolves further. It is *"Ubiquitous, customer-driven, virtualized, antifragile manufacturing":* customer-centric, highly customized, with hyper-connected factories and dynamic supply chains.

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INDUSTRY X is where it all comes together: *the nexus point of industry, AI, biotechnology, IoT: green, circular, cognitive manufacturing.* All pervasive and truly revolutionary, this is where the future really lies.

IN CONCLUSION

The speed and scope of technological change continues to amaze. As well as its direct effects in particular applications, there are major systemic impacts on business models, urban design, social behaviour and many more. Thinking through such consequences is a vital part of foresight activity.

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6. Biotechnology

Although there are some overlaps with the 4th Industrial Revolution Driver considered above – notably the use of AI – we think that trends in biotechnology are significant enough to be looked at separately.

GENE EDITING

The gene editing tool CRISPR/Cas-9, which won its inventors the Nobel prize in 2020, is an extremely powerful tool which has myriad applications in food and agriculture, and in medicine. Techniques such as *prime editing* are taking CRISPR's capabilities further – this technique "snips" just one strand of DNA rather than both as CRISPR does, which can be lethal to cells, and produce unintended edits.

Other advances are producing smaller versions of Cas-9 that can be transported by popular genome therapy vectors, such as the Adenovirus-Associated Viruses (AAV) and address an even wider range of diseases.

Epigenome editing could be even more versatile. These molecular tools target the epigenome, the chemical tags adorning DNA and its surrounding proteins that govern a gene's expression and how it ultimately behaves. Unlike DNA editing, where the changes are permanent and can include unintended results, epigenomic edits might be less likely to cause harmful off-target effects and can be reversed. They can also be more subtle, dialling a gene's impact up or down, rather than just switching it on or off.

*Agricultural applications c*an confer resistance to devastating plant diseases, pests and parasitic weeds; enhancing nutritional content; delaying ripening to reduce post-harvest losses; building resilience to climate impacts and unpredictable weather patterns, such as floods, drought and high temperatures; and improving grain quality and yield. These advances could be key to sustainable agriculture in Africa.

Kenya received applications for gene editing of banana and yam to resist two destructive plant viruses. Other gene editing research efforts are focused on making pigs resistant to Africa swine fever and sorghum that is resistant to the plant pest striga. The country sees this as a way of supporting its drive to become a middle-income country.

Pesticide-free plants: gene edited plants can manufacture RNA interference (RNAi) that kills off specific pests.

Drought-tolerant cattle: introducing the SLICK gene into cattle enables them to cope with temperatures increases and they are better suited to areas where temperatures are predicted to increase due to climate change.

Altering a mosquito's gut genes to make them *spread antimalarial genes* to the next generation of their species shows promise as an approach to curb malaria, suggests a preliminary study.

In medicine, CRISPR-Cas tools have the potential for therapeutic usage in different diseases, including genetic diseases, infectious diseases, cancers, and immunological diseases

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(autoimmunity and immunodeficiency). A wide range of diseases are being explored, including inherited blood disorders (such as sickle cell disease and haemophili), Duchenne muscular dystrophy, congenital genetic lung disease like cystic fibrosis, neurological disorders (Parkinson's disease, Alzheimer's disease, and Huntington's disease), and genetic deafness.

OTHER ADVANCES

Away from gene editing, other advances in biotechnology are creating interest. The carbon reduction opportunities of laboratory grown meat is one appealing area. *Lab-grown chicken* is already selling well in Singapore.

Biotech will also transform the manufacture of pharmaceuticals, industrial enzymes, and other organic chemicals. Genetically engineered yeasts and *bacteria have long been used to produce human insulin*. As the range of possible products increase, chemical production will become less like an oil refinery using heat and pressure to effect chemical changes, to look more like a brewery using yeast and other organisms in warm vats of microbial soups.

ETHICS AND LEGISLATION

Ethical issues around gene editing and genomics are beginning to emerge.

- *Affordability:* a common pill used to treat cholesterol might cost $5 per day, approximately $1,825 per annum, compared with a biotech drug that comes with a $20,000 per year price tag or more.
- *Intellectual property*: there were concerns with genetically modified seeds that farmers were being exploited; they were required to sign an agreement promising not to save the seed produced after each harvest for re-planting, or to sell the seed to other farmers, so must buy new seed every year. Fortunately, *two-thirds of CRISPR patents* are owned by universities, so there is the potential that similar issues can be avoided.
- *Privacy:* it will be possible to know that a 6-year-old may develop serious heart complications later in life. The question now is whether a prospective employer has the right to know about this. How will this knowledge impact the person's ability to get a job, mortgage, or insurance?
- *Precision medicine,* that takes into account individual variability in genes, environment, and lifestyle for each person predict more accurately which treatment and prevention strategies for a particular disease for each individual, in contrast to a one-size-fits-all approach. Naturally individually tailored treatments will be more expensive than generic ones leading to the prospect of increasing medical inequality.
- *Germ-line editing:* bioethicists generally believe that human genome editing for reproductive purposes should not be attempted at this time. Issues include safety, informed consent of future generations, "designer babies".
- *Stem cell research* on embryos: of particular concern to religious group.

Biotechnology advances also raise the prospect *of bio-terrorism* and the need to build defences to it CRISPR-Cas9 could theoretically also be used to alter pathogens to make them more transmissible or fatal. Alternatively, it could turn a non-pathogen, such as a harmless microbe, into an aggressive virus. The technique may even be able to alter a virus to make it

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dangerous for a larger range of species than it currently infects, or make it resistant to antibiotics or antivirals.

Countries are taking different views on *how to legislate gene-edited (GE) products*, whether they should be differentiated the older Genetically Modified Organism (GMO) technology, and its negative connotations to some consumers, commentators, farmers, retailers, politicians and lawmakers. The European Court of Justice (ECJ) ruled that all organisms produced by biotechnology were to be considered GMOs and to be regulated as such, while the US has called for more permissive policies on allowing new crop technologies. The UK approved draft regulations to simplify the approval process for research trials on plants aligning gene-editing with plants produced through traditional breeding rather than the previous alignment with GMO technology. It is possible that the drought in Europe, or food demands caused by climate change or war, may cause the *EU to change its position*.

The Food Standards Agency published *consumer research* that suggested that the more informed consumers were, or became, the more accepting of precision bred or genome edited (GE) food. Research also suggests that consumers tended to find GE food more acceptable than GM food. Most consumers felt it would be appropriate to regulate GE foods separately from GM foods – having recognised them as two separate techniques that should be treated as such. It is possible though that a "Frankenfoods"-style campaign by sections of the media could turn public opinion in a different direction.

As ever with new technologies, the scope for misuse is always present. Scientists have modified yeasts to *produce cannabis compounds, including the psychoactive chemical THC*. Drug enforcement agencies should expect to see cannabinoids and opiates and cocaine being produced by such methods.

INVESTMENT

Investment in biotech companies is growing rapidly, with some concerns it may be becoming excessive. President Biden recently announced funding of $2 billion for the *National Biotechnology and Biomanufacturing Initiative*, a "whole-of-government" effort to further biotechnology and biomanufacturing innovations in health, climate change, energy, food security, agriculture, supply chain resilience, and national and economic security. Over $1bn was raised in *venture capital funding* for gene editing in 2021.

As always, SAMI likes to think through the second-order effects of change. With biotechnology, most of its effects seem to be beneficial, but regulators do need to be aware of the ethical concerns and the possibilities for abuse.

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7. Social Attitudes

The sixth and last of SAMI's Drivers of Change is "Social attitudes", in particular how they are changing with different generations. Arguably this is one of the most fundamental drivers, as it underpins political and economic positions, climate change action, and willingness to adopt new technologies. We are focussing mainly on the UK and US, but will also touch on attitudes elsewhere.

Different generations' attitudes likely vary largely because of different experiences in their formative years. It used to be assumed that people's attitudes changed as they got older, becoming less radical and more pragmatic. But it is beginning to appear that the views of different cohorts are now remaining distinct as they age.

Typically, commentary on changing generational attitudes references cohorts such as Baby Boomers (born 1946-64), Millennials (born 1981-1996) or Gen Z (1997-2012). Of course none of these groups is homogeneous and attitudes will vary. But for the purpose of identifying general trends this approach seems to be helpful.

The *British Social Attitudes* report published earlier this year showed continued progressive attitudes:

- No substantial reaction so far against the expansion of government spending
- Signs of greater concern about inequality post COVID
- Nearly three-quarters said the pandemic has made them more sympathetic toward others' needs and that they intend to take actions to have a positive impact on their communities.
- Attitudes towards welfare had already become more supportive beforehand.
- For the most part, the public has become more liberal in its attitudes towards 'culture wars' issues, though voluble groups remain.
- Remain and Leave supporters have different views on these issues.
- 35 percent of people in Gen Z know someone who uses "they/them" pronouns.

By September 2022, more people were in favour of *changing the voting system* rather than keeping it as it is for the first time.

MONEY AND WORK

Britain's millennials earned £8,000 less during their 20s than their predecessors and are at risk of being the first cadre of workers in modern times to see their *lifetime earnings fall.*

Home ownership is considerably lower amongst young people than it used to be. The phenomenon of "*boomerang children*", returning to live with their parents is increasing: six-in-10 single 20 to 34-year-olds (3.5 million) without children now live with their parents; the proportion has risen from 55% to 63% over the last 10 years.

An aging population means there is a combination of different generations in the workforce with significant implications for incentive and reward schemes of larger organisations. Compared with earlier generations, *millennials value* greater flexibility, appreciation, team

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collaboration, progression and career opportunities, and, above all, a healthy work/life balance. Gen Z, however, is likely to value security and stability more highly.

HEALTH

Depression is on the rise among *millennials,* many of whom suffer from loneliness, money stress, and burnout in the workplace. Since 2013, millennials have seen a 47% increase in major-depression diagnoses. The overall rate increased from 3% to 4.4% among 18- to 34-year-olds. Much of this can be ascribed to work and finance challenges, but some commentators also identify *social media* as a factor because of the greater pressures it brings to compare one's life with others. Close to half (48%) of Gen Z and 44% of millennial respondents in a Deloitte survey said they are *stressed all* or most of the time.

On the positive side, the younger generations are being more open about their issues and destigmatizing therapy, with high-profile individuals admitting mental health challenges.

Millennials and Gen X *drink less alcohol* than their predecessors – causing a rise in sales of *"nolo" drinks* of 30% since 2016. The pandemic apparently *reinforced this trend.* This group also *smokes less* than before. Although younger age groups smoke more than older ones, the prevalence of smoking since 2011 has fallen most in those groups; down by 8 percentage points among 18–24-year-olds (from 26% to 18%). However, young people do seem to be vaping – which is *increasingly popular among those* who are not former or current smokers.

ETHICS

Millennials are twice as likely as the overall investor population to *invest in companies* targeting social or environmental goals. They are also twice as likely to check product packaging *to ensure sustainability* and similarly as likely to purchase from a brand because of the company's social and/or environmental impact. They want their work to reflect their values: 87% of those born between 1990 and 2015 believe that "the success of a business should be measured in terms that go further than its financial results".

More than a third (35%) of UK employees are willing to quit their jobs if their employer takes inadequate *action to reduce its carbon footprint.* This is particularly so among Gen Z employees, with 53% of 18- to 24-year-olds willing to consider leaving an employer based on net zero credentials.

Climate change tops the list of *vital challenges* of our time, say young people. Amnesty International's survey of over 10,000 18-25-year-olds across 22 countries reveals that 41% of respondents cited global warming as the most important issue facing the world. 36% identified pollution as a key issue.

Millennials and Gen Z'ers both say they will make a special effort to more actively patronize and support businesses—especially *smaller, local sellers*—after the pandemic.

35% of the UK population stated that they *trusted the national government*, lower than the Organisation for Economic Co-operation and Development (OECD) average (41%). The interview period is not stated – the figures were published on 13 July 2022 – so it can be assumed this figure has reduced following the shambolic summer and autumn.

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Citizens *trust legacy media* more than the internet and social networks and put particularly high trust in public service media. They trust legacy media more than they trust their governments and political parties. Trust in social networks has constantly declined, reaching its lowest since it was first measured in 2014.

GLOBALLY

Running in parallel with the emerging poly-nodal world, Western leadership is increasingly being challenged. Reaction to *"White Saviours"* in Africa is now very strong, as is the reaction to a continued western attitude of treating Africa as just one country.

In *Tanzania*, people aged 15 to 24 take a very entrepreneurial attitude: 50% want to be a business magnate and a further 18% an entrepreneur.

The current uprising in *Iran,* beginning as a reaction to the "Morality Police", seems to be being predominantly driven by young women and girls, and opposed largely by older, religious men.

Chinese youth is rebelling against over-demanding working environment, with the "lying flat" (*tang ping)* movement of doing no more than necessary extending into "let it rot"(*bailan)* – disengaging completely. The attitude is widespread enough to indicate a real sense of pessimism and disillusionment among China's young generation. Will this at some point morph into active revolt?

Social attitude change is driven by the young. Worldwide, the young seem to be more open, more socially liberal, and demanding change, in the face of political movements dominated by the old. The young see these movements as protecting the assets and power the old have gained, rather than acting for the whole population. Young people are primarily motivated by single issues (abortion in the US, environmentalism, conscription in Russia), but that single issue focus unpredictably morphs into a desire to see a wholesale change in government policy (Iran).

The young are a potent political force, with many justifiable grievances and much potential power. That they have not yet chosen to use that power in a concerted manner does not mean that they will not at some stage in the future.

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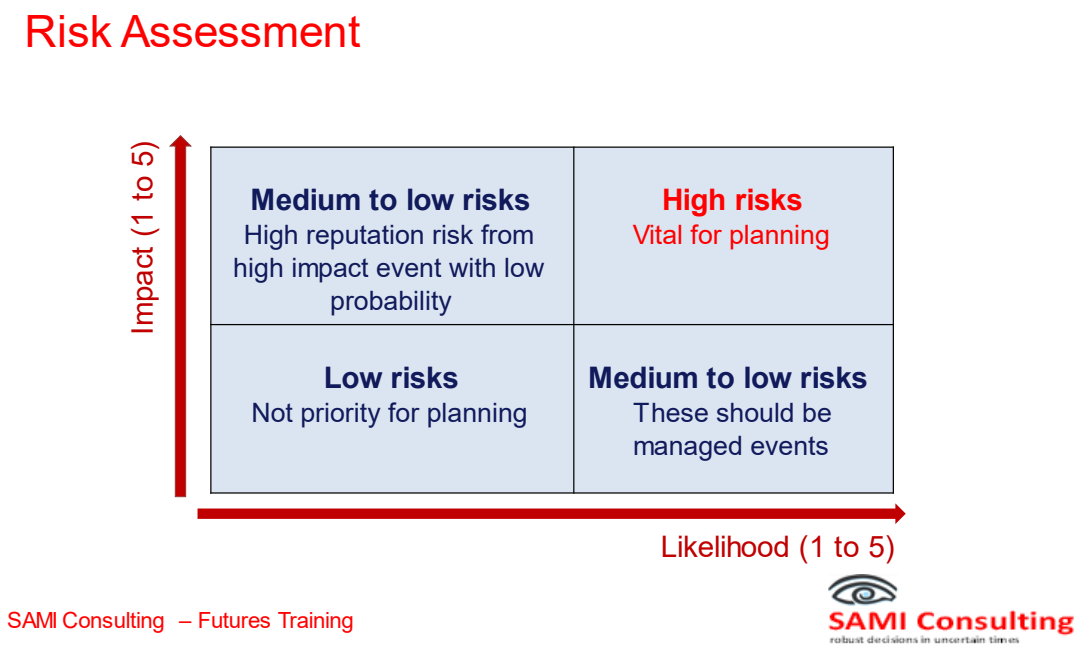
8. Using Drivers of Change

Drivers of change can be used in foresight projects in several ways. At the simplest they can be just a briefing for senior managers to create an increased awareness of the ways in which the world is changing, which then in an unstructured way informs strategy development. More analytically, they can be used to set off a series of work packages exploring the impacts on the organisation and its environment.

They are also a possible stimulus for scenario planning. In a workshop setting, the team could explore the risks and uncertainties that each of the drivers bring, and add to them other issues seen to be relevant. These would then be assessed by degree of importance and likelihood.



From there, key risks can be identified and used as the axes of uncertainty in a scenario cross, creating four distinctly different views of the future.

SAMI Consulting Working Papers are based on posts published at samiconsulting.co.uk. They reflect the company's thinking on issues of current importance, viewed from the perspective of futures thinking and strategy. Working Papers examine issues at the time of writing, and are subject to change as the situation changes.

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