Ministry of Defence

Strategic Trends Programme

Global Strategic Trends - Out to 2045

Fifth Edition

Conditions of release

Global Strategic Trends describes a strategic context for Defence and security looking out to the middle of the century. It takes a comprehensive view of the future derived through research headed by the Development, Concepts and Doctrine Centre (DCDC).

This publication is the fifth edition of Global Strategic Trends. It is benchmarked at 30 April 2014. Developments taking place after this date have not been considered.

The findings and deductions contained in this publication do not represent the official policy of Her Majesty's Government or that of United Kingdom's Ministry of Defence (MOD). It does, however, represent the view of the Development, Concepts and Doctrine Centre, a department within the MOD.

Foreword

The Development, Concepts and Doctrine Centre's Strategic Trends Programme is a continuous programme of research that seeks to provide policy-makers with a context for long-term decision-making. This, the fifth edition of Global Strategic Trends, builds on previous editions and a respected body of work that benefits from continual engagement with a wide range of contributors from academia, business and government both domestically and internationally. The extent of across UK Government engagement – together with increased levels of international consultation and peer review – are particular strengths of this edition.

The challenge of looking 30 years ahead cannot be overstated. Importantly, Global Strategic Trends does not seek to predict the future, instead it describes plausible outcomes on the basis of rigorous trends analysis. It is a truism that in an increasingly complex, competitive and connected world, the challenge is not responding to what we know today, but rather preparing for what tomorrow might bring.

Looking out toward the middle of this century, the opportunities and challenges abound. Demographic change will see developed nations adapting to aging populations, while developing nations face the challenge of rapid population growth that won't necessarily be matched by economic development. The pace and breadth of technological advancements will change our perception of our role in the workplace, reveal new opportunities for health advances and facilitate the deepening of global communications. But as access to technology increases, we will face new risks to our security both at home and abroad. The industrialisation of the developing world will present resource and environmental challenges while generating wealth and prosperity for some of the most impoverished nations. In the West in particular, a rise of individualism and, amongst many, a growing sense of disconnection from long-established governing structures will challenge traditional systems. The growth of cities will provide opportunities to make better use of the world's resources but will expose many of the millions living in coastal cities to the risks of flooding as rising sea levels and more frequent and destructive weather events begin to test resilience. And climate change and the consequences of warming will affect food and water availability for many.

Ultimately, Global Strategic Trends is designed to inform policy-makers as they grapple with the opportunities and threats that the future could bring. And the choices that they make could have as great an impact on the future as the trends themselves.

Rear Admiral John Kingwell
Director, Concepts and Doctrine

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Introduction

Global Strategic Trends (GST) describes a strategic context for those in the Ministry of Defence (MOD) and wider Government who are involved in developing long-term plans, policies and capabilities. Without a strategic context there is a risk that planners, policy-makers and capability developers may assume a future that adheres to preconceived thoughts and assumptions. As well as providing a strategic context, this fifth edition of GST (GST 5) identifies long-term threats and opportunities, out to 2045. GST does not attempt to predict the future – it cannot. Rather, it describes those phenomena that could have a significant impact on the future and combines these differing perspectives to produce a multifaceted picture of possible outcomes.

The need for the MOD to set out the future strategic context was articulated in the 1998 Strategic Defence Review. To meet that requirement, the Strategic Trends Programme was started in 2001 and the first edition of GST was published in 2003. Subsequently, GST, along with the Future Character of Conflict (which will be renamed the Future Operating Environment when it is released in 2014) have been key elements of the MOD's contribution to both the National Security Strategy and the Strategic Defence and Security Review – and we expect them to play similar roles in the future.

GST is the first step in a series of MOD long-term planning activities. By providing a global context, further work will then be able to examine its implications and develop policy and capability options to meet the resulting challenges. While GST is produced principally for MOD it has utility for others involved in long-term planning. We have benefited from considerable engagement with those outside MOD – from academia, business and government both domestically and internationally. In so doing, we have deliberately attempted to avoid a single, subjective perspective.

The starting point for GST is identifying trends (discernable patterns of change) – an example is the growth in world population. The next step is projecting those trends forward 30 years, analysing their potential consequences and using this to build a series of pictures of what the future could look like in 2045. Finally, these components are combined to produce a strategic context, including defence and security implications, against which policies, capabilities and plans can be tested and refined. Key **scenarios** illustrate how these trends could interact and **shocks** provide the reader with examples of how the strategic context could be radically altered by unexpected events. In addition, **alternative outcomes** emphasise that there are several possible ways trends could impact on the future.

Following a complex mapping process (explained further in the methodology section) we have identified 13 clusters of trends and drivers with particularly strong linkages. This provides the overall structure for the document, rather than the STEEP method[1] used in GST 4. Some trends (most notably those relating to economics, religion, technology and globalisation – themes that

1 'STEEP' analysis provides broad headings for grouping information: social, technological, economic, environmental and political.

would have been called 'ringroad issues' in previous issues of GST) run through all of the following groups, and are discussed as they arise rather than in their own sections. We hope this brings them to life more clearly. The 13 overarching themes are:

- Demography
- Gender
- Urbanisation
- Resources
- The Environment
- Health
- Transport
- Information
- Education
- Automation and work
- Corruption and money
- Identity and the role of the state
- Defence spending and capabilities.

Contained within these sections are a number of scenarios which explore some of the most important connections and inter-dependencies between trends, giving a brief indication of a few of the challenges and opportunities that these linkages could produce. While we have set out what we believe are the most plausible trends, our work on strategic shocks has shown how significant outlying disruptive events can be. The most significant of these shocks are discussed with the relevant trends. Although GST 5 may initially seem to have a rather gloomy, Malthusian[2] outlook, we believe that policy-makers can have a significant impact on the future, and hence there are considerable grounds for optimism.

"We hope you will refer to GST 5 regularly and draw your own conclusions from the information we have presented."

For those readers who have a particular interest in the way that trends are likely to affect specific parts of the world, the second part of GST 5 focusses on what 2045 may look like in eight regional groups as well as Space:

- Northern America
- Latin America
- Europe
- Middle East and North Africa
- Sub-Saharan Africa
- Central Asia
- South & East Asia and Oceania
- Polar regions
- Space.

There is, unavoidably, a huge degree of uncertainty in what we describe. We will have got some things wrong, there will be unidentified shocks and surprises, as well as phenomena that we had not envisaged. Parts of the document may, at first glance, seem contradictory. There will inevitably be inconsistencies because we are aiming to describe a variety of possible futures rather than predicting a single, certain outcome. Although we try to give a picture of the world in 2045, you may see references to different dates in the document where we have drawn on sources not perfectly aligned with our timeframe. Because we are looking so far into the future, much of what we describe is, inevitably, based on extrapolation and (a degree of) imagination. Extrapolation may not, of course, be linear. Unlike the method used in GST 4, we have not attempted to assign probabilities, given the inherent uncertainty – that could be misleading and simplistic. Instead, we hope you will refer to GST 5 regularly and draw your own conclusions from the information we have presented. This, we believe, will be the most effective way of helping you think about the future and how to embrace it.

2 The view that "the population tends to increase at a greater rate than its means of subsistence, resulting in the population checks of war, famine and epidemic". Concise Oxford English Dictionary, 11th edition.

How to use

Synopsis, Executive summary and key implications for defence and security

This section provides a brief overview, summarises the major trends, drivers and their implications, as well as highlighting key implications for defence and security.

Part 1 – Thematic

This part brings together important trends and drivers under related themes. The relationships between themes, trends and drivers are described and the implications for defence and security are highlighted. Where a geographical relationship has been identified, the theme is cross-referenced to the appropriate geographical analysis (Part 2).

Part 2 – Geographic

Drawing on region-specific research, and expanding on the observations made in Part 1, this part considers regional and (where appropriate) country-specific effects of themes, trends and drivers.

Shocks

Throughout GST 5, text boxes containing shocks will alert the reader to the inherent uncertainty when looking 30 years into the future. Events could occur that would disrupt trends, leading to a future that looks very different. These events – or 'shocks' – only have a low probability of occurring, but because of their potentially high impact, it is important to consider some in more detail, allowing for possible mitigating action to be taken. The terrorist attacks of September the 11th or the 2008 global financial collapse are historical examples of low-probability events happening with significant long-term consequences.

Scenarios

Scenarios illustrate ways in which trends and drivers from multiple themes could interact.

Alternative outcomes

When discussing trends and drivers, we highlight the outcome judged to be the most likely. However, there are several credible ways that particular trends could interact and affect the future. The alternative outcome boxes highlight other plausible ways that trends could develop.

Thematic

Each theme has an icon and its own colour which is used to index and cross reference information.

The key trends, drivers and the potential implications for each theme are summarised. Supporting details can be found in the main text.

Alternative outcomes highlight other plausible ways that trends could develop.

Scenarios illustrate ways in which trends and drivers from multiple themes could interact.

The implications for defence and security are summarised at the end of each theme.

Geographic

Each regional grouping is shown together with a list of the countries that comprise the group.

A representation of the region provides a quick reference and helps to situate the area under discussion.

The key trends, drivers and the potential implications for each region are summarised. Supporting details can be found in the main text.

Shocks - events that could occur that disrupt the trends described - are highlighted.

Synopsis

Our lives and the world we live in will almost certainly change over the next 30 years, with the impacts felt by all. We will probably live longer and know more. By 2045, the global population is likely to grow by two billion, with far-reaching consequences for how, and where, we live. Changing demographics could create new threats and opportunities, with aging populations in many developed countries and youth bulges in some developing countries. This is likely to be coupled with a growing number of migrants across the globe as we become more connected. Gender inequality is likely to remain in 2045, driving poverty and insecurity in large parts of the world. Governments may come under immense pressure to address the coming challenges, and if social expectations fail to be met, social unrest or even violence could ensue. Over 70% of a growing global population looks set to live in urban areas by 2045. Where urbanisation is managed successfully, it could spur economic growth and create a better quality of life. Handled poorly, people may live in slums, without adequate infrastructure and services – driving an increase in communicable diseases and poverty, possibly leading to violent insurgencies.

With more people living longer, demand for resources will almost certainly grow. We are likely to need more food, water and better sanitation. However, without successfully managing water stress, including more effective international cooperation, it is likely that 3.9 billion people will suffer water shortages. Demand for energy could more than double by 2045, although non-polluting power sources and better energy storage may offset some of our reliance on coal and hydrocarbons.

As we increase the stress we place on the natural environment, our need to understand, protect and preserve it will almost certainly grow. Climate change, a rise in sea levels, desertification and reducing biodiversity are all issues that could affect us even more over the next 30 years. They are likely to impact on agricultural production and fishing, and could exacerbate humanitarian crises. It is possible, however, that new technologies may hold solutions to some of these problems.

Physical inactivity, unhealthy diets and increased life expectancy could lead to an obesity 'epidemic' as well as rises in non-communicable diseases such as dementia. But significant improvements in health and medicine could let us live longer and be more productive. We are likely to be able to make medical diagnoses faster, more cheaply and with greater accuracy. Innovative methods could be introduced for drug and treatment delivery. Medicines may even be tailored to a person's genetic make-up, providing safer and more effective treatment.

Technological progress is occurring in almost all aspects of human life and is likely to cause significant change by 2045. Everyone and everything seem certain to become more connected, with revolutionary advances in how we acquire, store and analyse information. If current trends continue, there are likely to be dramatic increases in computing power that could enable us to predict and monitor many aspects of our lives and surroundings. This may mean that complex global issues can be modelled and predicted, such as climate change, population movements, disease patterns and economic trends. But people are likely to find it increasingly difficult to go

> *Our lives and the world we live in will almost certainly change over the next thirty years, with the impacts felt by all.*

'offline' and maintaining privacy could become more challenging. There could also be an increasing threat of cyber attack from criminals and terrorists as information, communications and critical national infrastructure become more integrated.

Our changing technological world is likely to have a tremendous impact on the way we are educated in the future. Improved computing power and 'Big Data' means that teachers are likely to have access to vast quantities of information. Learning is likely to be stimulated through exercises, games and simulations – enabled at the touch of a button. Although face-to-face education is unlikely to disappear, teachers will probably become more like 'learning advisers', guiding students through digitally-delivered, personally-tailored education. Social networking is likely to play an important role in collaborative learning, through real-time discussion and virtual classrooms. Learning is unlikely to end at school and university – rather, lifelong learning will probably become the norm. There is likely to be a growing emphasis on the transferability and constant upgrading of qualifications. Global inequality in education is likely to remain, particularly as a 'digital' education is unlikely to be available to all. There will probably still be a gender gap, despite near-parity for girls and boys at the primary level. However, the disparity between developed and developing countries is likely to reduce. It is even possible that by 2045 the majority of the world's children will have enjoyed a university or higher-level education.

Technology is highly likely to change our working environment. By 2045, robots or 'unmanned systems' (able to carry out complex tasks without a human operator's direct involvement) are likely to be as ubiquitous as computers are today. Machines are likely to become more sophisticated and lifelike. We could also see robots used in many more areas of work and society, including caring roles, customer-service, surgery and in combat. This will probably mean a period of adaption and change, as robots take on some traditionally 'human' roles. There will almost certainly be challenges to overcome, such as establishing whether we can learn to 'trust' robots. But it is not just the increasing use of machines that has the potential to change the way we work. As the population alters, the workforce may change as well – people are likely to work longer. We are likely to place a greater emphasis on flexible working, short-term contracts and working away from the office.

So much change will almost certainly affect our perception of identity. And again, technological developments are likely to drive change. Advances in human augmentation may mean we can enhance our sensory capability, become more physically able and improve our cognitive functions. However, it is unlikely this technology will be available to all, potentially contributing to the increasing inequality the world faces.

How the state functions in this changing world will almost certainly alter. Individuals may feel less connected to their country of origin as they migrate more frequently and identify more strongly with online communities of interest. Private companies and non-governmental organisations could grow in power, providing services that used to be the responsibility of the state. Internationally, countries may be more closely connected, with stronger trading and political blocs.

Widespread and challenging implications for defence and security will almost certainly be generated by this increasingly connected world, with its rapidly advancing technology and evolving societies. The face of some armed forces may change, with an increasing use of unmanned systems and women in combat roles. Militaries and security forces may be asked to meet the challenges of more humanitarian disasters, and attacks by non-state actors and cyber-criminals may increase. As more people live in cities, it is likely that some future adversaries will be found in larger, more complex urban environments, possessing a greater level of information and better access to technology than they do today.

Executive summary

This fifth edition of Global Strategic Trends (GST 5) aims to describe possible futures to provide a strategic context for policy- and decision-makers across Government. Thirteen broad thematic areas have been identified, with eight geographic regions and a section on space. Some trends (most notably those relating to economics, religion, technology and globalisation) are so important that they run through all of the subject areas, and are discussed as they arise rather than in their own sections, to bring them to life more clearly. In the process of identifying threats, challenges and defence and security implications for policy- and decision-makers, there may be a tendency for the document to seem rather negative in its outlook. This is an inevitable consequence of its purpose. There is of course scope for human ingenuity to have a significant impact on the future, and hence there are considerable grounds for optimism.

Demography

The global population is likely to grow to between 8.3 and 10.4 billion by 2045, largely because of increasing life-expectancy, declining levels of child mortality and continuing high birth rates in many developing countries.[1] Growth is not likely to be evenly distributed and will probably be slower in developed countries. Some, including Japan and parts of Europe, are likely to experience a decline in population. In developing countries, rapid population increase and urbanisation will probably challenge stability. Age and gender imbalances may exacerbate existing political and social tensions while a growing youth population, especially in the Middle East, Central Asia and sub-Saharan Africa, could provide a reservoir of disaffected young people. Conversely, if harnessed, they could provide a boost to their economies. Migration is likely to increase, with people moving within, and outside, their country of origin to seek work or to escape the effects of climate change.

Gender

Global gender equality and opportunity gaps will almost certainly continue in economic, social and political spheres out to 2045. Although women's autonomy is likely to gradually increase in most regions, entrenched gender disparities will probably remain as major drivers of poverty and insecurity. As is the case today, women are likely to have greater opportunities and autonomy in developed countries than elsewhere in the world, but are unlikely to achieve total parity with their male counterparts, particularly when social expectations inhibit the role of women in society. In some regions of the world, women's rights and feminist movements are likely to continue to face a 'backlash' from those with vested interests in maintaining the status quo.

Urbanisation

With 70% of the global population likely to live in cities by 2045, urbanisation will be a particularly important theme in developing countries. Urbanisation is likely to enhance economic and social development, but – without mitigation measures – may also lead to pressure on infrastructure (and the environment) which could contribute to social tensions within the urban population.

1 UN categories are used for 'developed' and 'developing' countries.

New technologies are likely to enable step changes in speed and efficiency of mass transport

"Demand for resources of all kinds is likely to increase out to 2045, as the world's population grows."

Urbanisation and the effects of climate change are likely to result in an increase in the magnitude of humanitarian crises, particularly since the majority of urban areas will almost certainly be either on, or near, the coast, making these cities vulnerable to flooding.

Resources

Demand for resources of all kinds is likely to increase out to 2045, as the world's population rises to around nine billion. While the demand for food is expected to grow, some countries are likely to experience significant declines in agricultural productivity. Water shortages are likely to be particularly acute in many areas, exacerbated by increasing demand and climate change. In the 2045 timeframe, coal and hydrocarbons are likely to remain the most important sources of energy, with renewable and nuclear energy likely to make an increasing contribution.

The Environment

A growing population will demand more food and water, increasing the strain on the environment out to 2045. As centres of population cluster in vulnerable areas such as coastal regions, the consequences of adverse weather are highly likely to be felt more keenly. By 2045, climate change is likely to have more noticeable effects. Without mitigation, rising sea levels will increase the risk of coastal flooding, particularly in regions affected by tropical cyclones. Droughts and heatwaves are also likely to increase in intensity, duration and frequency. Some of these events could precipitate natural disasters which, because of the interdependencies enabled by globalisation, may have consequences far beyond the site where the disaster occurs.

Health

Developments in technology are likely to lead to significant improvements in medicine and health, such as the potential for developing cures for some cancers by 2045. Advances in diagnostic techniques, the development of artificial organs and mind-controlled prosthetic limbs mean that we are highly likely to live for longer and have more productive lives. But new challenges to good health will almost certainly emerge. Rising physical inactivity and unhealthy diets are likely to contribute to an obesity epidemic and a rise in non-communicable diseases. Antimicrobial-resistant pathogens could be widespread by 2045, making post-operative infections potentially lethal.

Transport

New materials, manufacturing techniques and power systems, as well as advances in information technology, are likely to open up new opportunities for automated transport and generate step-changes in speed and efficiency. Driverless transport is likely to be widespread by 2045, providing greater independence for the elderly and impaired. Unmanned systems could play a key role in the mass delivery of people and goods. New developments in super-sonic flight could make sub-orbital space transport a commercial reality in the next 30 years.

Information

Revolutionary advances in how we acquire, store and analyse information, together with dramatic increases in computer processing power, are likely to give us the ability to predict accurately a wide range of phenomena, from crime hot-spots to the effects of climate change. As everyday objects are increasingly connected to the Internet, this vast network of sensors is likely to gather data on more aspects of our lives and the environment, making it hard for anyone to go 'off the grid'.

Education

Increasing computing power, growing access to the Internet and 'Big Data' are likely to have a transformative effect on education, with an increasing blurring between online and offline learning. Education levels will almost certainly continue to rise across the globe and for both sexes. At the same time, educational institutions could face a series of major challenges, including facilitating smoother transitions from education to work and encouraging lifelong learning to ensure the workforce can adapt to a changing job market. These pressures may force educational institutions to provide more informal, distance and personalised learning. There is likely to be a growing emphasis on the transferability and constant upgrading of qualifications, as well as a shift towards more personalised forms of assessment that use a range of technologies to trace the paths of individual learners.

Automation and work

Robots or 'unmanned systems' – machines capable of carrying out complex tasks without directly involving a human operator – are likely to be as ubiquitous in 2045 as computers are today. Unmanned systems are increasingly likely to replace people in the workplace, carrying out tasks with increased effectiveness and efficiency, while reducing risk to humans. This could ultimately lead to mass unemployment and social unrest. As robots become more lifelike, perhaps capable of appearing to express emotion, interactions with people are likely to become more complicated. The increased capability of robots is likely to change the face of warfare, with the possibility that some countries may replace potentially large numbers of soldiers, sailors and airmen with robots by 2045. However, military decision-making is likely to remain the remit of humans for ethical reasons, at least in western countries. Others may not be so willing to make the same trade-offs between speed and accountability.

"Unmanned systems are increasingly likely to replace people in the workplace."

The proportion of older workers in the global labour force is likely to increase out to 2045, with a possible corresponding decrease in opportunities for younger people. Flexible working practices are likely to become more widespread, with people employed on shorter-term contracts and a growth in working remotely. Workers will probably have less predictable income and increasing economic insecurity. By 2045, there is likely to be greater equality between men and women in the jobs market, particularly in developed countries. In part, this may be driven by a global shift away from manual labour, towards a more knowledge-based economy.

Corruption and money

If unchallenged, corruption is likely to continue to exacerbate global inequality and conflict. By 2045, consistent attempts to curtail corrupt practices are likely to be made by national governments, international governing institutions, the private sector and

"Personal privacy will very probably be increasingly difficult to achieve in the years leading up to 2045, as identity is increasingly defined by online activities."

non-state actors. Technology is highly likely to play a significant role in both enabling and combating corruption.

State-backed currencies will almost certainly still be the dominant form of money in 2045, although alternative currencies are likely to expand, constituting the main shift in the financial landscape. Criminal transactions may increasingly be made using alternative currencies, with a possible growth in the anonymous raising and transferring of funds by terrorist groups. Governments could have less influence over alternative currencies and, as a result, may be less able to shape the global financial system or raise revenues through taxation. A single international currency within the timeframe is improbable, with the US dollar likely to remain the most important global currency by 2045. China is likely to allow greater financial liberalisation, contributing to its possible overtaking of the US in terms of GDP within the next 30 years. This is likely to contribute to some erosion of the pre-eminence of the dollar as the dominant global reserve currency. Increased globalisation could also make transmission of financial shocks more widespread.

Identity and the role of the state

The state will almost inevitably be the dominant actor in international affairs in 2045. Private or semi-state owned companies and non-governmental organisations are likely to exert increasing influence, but are less likely to exercise state-like legal and decision-making powers. Individuals may define themselves less by their nationality, with growing migration and stronger links to virtual communities. Rising costs, demands, technical complexity and need for specialisation could see private and other non-state entities increasingly functioning as the primary providers of those services that states have traditionally delivered, such as security. Some states may lose their monopoly on force, as private security contractors are increasingly employed and as some private companies take more responsibility for their own security. The extent to which these changes happen under the control of state-based decision-makers is likely to vary between countries according to their stability and forms of governance.

Personal privacy will very probably be increasingly difficult to achieve in the years leading up to 2045, as identity is ever-more defined by online activities. People are likely to demand higher levels of privacy protection from governments and businesses. Religion will probably remain a significant component of identity, with the spread of representative governments providing the space for some religions to become increasingly politically assertive. A range of technological enhancements have the potential to transform human identity by improving sensory perception, physical performance and perhaps even giving us the ability to control fear and other emotional states.

Defence spending and capabilities

Chinese defence expenditure is likely to rival that of the US over the next 30 years, reflecting China's growing economic strength. These two global powers are likely to spend far more on defence than any other country, accounting for almost half of the world's total defence spending by 2045. India's defence budget could see it occupying a 'second tier' by 2045. Russia is likely to increase defence spending, although not quickly enough to match that of China, the US or India. European countries are likely to continue to spend substantial amounts on their armed forces, although their spending is unlikely to increase significantly unless a major threat emerges. Advances in technology are likely to lead to increasingly effective non-lethal capabilities and increase the precision of weapons. This is likely to alter the nature of conflict.

Northern America

By 2045, Northern America's population is likely to grow to between around 394-478 million and become more ethnically diverse. Climate change is likely to open up shipping routes during the summer months, as well as new areas for extracting minerals and hydrocarbons in the Arctic. However, it is also likely to cause significant harm through heatwaves, droughts, and flooding across the region. Northern America's economic outlook is positive, boosted by newly accessible energy reserves, and it is expected to integrate ever-more closely with the global economy. While security challenges (including the threat

of terrorism) will probably endure, the region is likely to remain stable and politically influential. The India-US relationship has the potential to become significant in the timeframe, but the pre-eminent relationship for the region is likely to be between China and the US, particularly as trading partners. However, there will almost certainly remain a number of issues that could give rise to tensions between the two countries.

Latin America and the Caribbean

Latin America and the Caribbean are likely to remain politically and economically fragmented, with individual countries pursuing bilateral relationships rather than forming a strong unified bloc. Brazil and Mexico are likely to show the strongest growth in the region, with both countries likely to be major global economies (in terms of GDP) by 2045. Rising sea levels and extreme rainfall are likely to expose a number of large and populous cities in coastal regions around South America to additional flooding risk. Socially, weak governance is likely to continue to inhibit progress in a number of countries, with the growing consumer class being increasingly vocal in its challenge to regimes. Some Latin American countries are highly likely to have mature military-industrial complexes and armed forces capable of performing on the global stage by 2045. Regional stability is highly likely to endure, although producing and globally distributing narcotics will almost certainly continue, with an increasing 'home market'. However, the emergence of a fully-fledged narco-state is unlikely.

Europe

Europe is likely to remain a substantial part of the global economy, with the euro and the single market still likely to exist by 2045. EU membership is likely to expand, although it is unlikely that all countries who wish to join will be included. The effects of climate change are likely to be less severe in Europe than in most other regions, although increased water scarcity in the south may limit agricultural productivity there. Energy consumption is likely to decrease out to 2045, although hydrocarbons will probably continue to be the continent's main source of fuel. Europe

Europe is likely to remain a substantial part of global economy

is likely to face a range of security challenges, but disagree internally over how to address them. As the US focusses increasingly on Asia, Europe will almost certainly be expected to make a greater contribution to its own security. Russia is likely to continue to be a major power, maintaining a substantial capability for regional intervention by 2045. China and Europe are unlikely to view each other as threats and may become partners in managing future crises.

Middle East and North Africa

Over the next 30 years, the Middle East and North Africa (MENA) are likely to remain volatile areas, with high potential for tension and some violent conflict. The aftermath of the Arab uprisings of 2011 may still resonate in some countries, with civil unrest likely. Identity politics and sectarianism will almost certainly be key characteristics of the political landscape, constituting a serious challenge to good governance. Countries in MENA are unlikely to be able to break the cycle of power politics, patronage, religious tension and authoritarianism. Social, environmental and economic issues will probably continue to threaten the region's stability out to 2045, including an under-employed young population, a decline in natural energy resources and the effects of climate change.

"Some Latin American countries are highly likely to have mature military-industrial complexes and armed forces capable of performing on the global stage by 2045."

Sub-Saharan Africa

Sub-Saharan Africa will almost certainly remain a region of significant political and economic differences by 2045 but overall the region's economy should grow – possibly rapidly. However, economic performance is likely to vary sharply from country to country, with a lack of infrastructure and political instability likely to continue to provide some of the biggest challenges to sustained growth. The region is likely to see the fastest rise in population growth of anywhere in the world, with some countries' populations more than doubling by 2045. Governance in the region is likely to improve and the current trend towards representative government is likely to continue, although this will probably be resisted by some authoritarian regimes, possibly leading to violence. The risk of state-on-state conflict is likely to reduce but will almost certainly remain a concern. By contrast, the threat from intra-state conflict and from terrorism is likely to endure - and could worsen. The African Union's ability to deal with crises is likely to improve, but it will probably still require international assistance for more demanding situations. Technology is likely to facilitate links between different parts of the region and with the wider world, thereby increasing economic productivity and improving governance. If current trends continue, most people in the region are likely to have access to the Internet by 2045. Climate change is likely to have a severe impact on some parts of sub-Saharan Africa, with agriculture particularly badly affected. The region is likely to continue to face significant rates of infection from communicable diseases such as HIV/AIDS and malaria. But it is conditions such as diabetes and cancer that are likely to pose the greater health threat by 2045.

"As Arctic and Antarctic sea ice retreats, many areas that are currently inaccessible could become open to commercial exploitation, particularly of oil and gas."

Central Asia

Despite the divergent paths taken by the five Central Asian republics (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) since their independence from the Soviet Union, each remains vulnerable to social and economic risks. These potential problems stem from internal threats caused by weak infrastructure and institutions, as well as their relations with external actors. As a result, the region is susceptible to ethnic conflict, sudden political transitions, economic shocks, food insecurity and natural disasters – all potentially posing strategic threats beyond Central Asia to the rest of the world.

South & East Asia and Oceania

China and India will almost certainly continue to be the dominant powers in the region by 2045, with their economies ensuring that South & East Asia makes the biggest contribution to the world's GDP. Japan is likely to continue to have the region's third-largest economy. In Oceania, Australia will almost inevitably remain the dominant power and have the largest economy. South & East Asia and Oceania are likely to continue to contain over 50% of the world's population by 2045, presenting both benefits and challenges. China and India are likely to continue to devote considerable resources to ensuring economic growth and both countries are likely to continue to seek a strong economic relationship with the US. The ways that China and India manage their societies' demands and their internal methods of governance will be important to the region's development. Both countries are likely to become increasingly dependent on the global economy for their long-term stability, prosperity and security.

Polar regions

Climate change is the principal driver of change in the Arctic and Antarctic, with increasing temperatures and precipitation. As Arctic and Antarctic sea ice retreats, many areas that are currently inaccessible could become open to commercial exploitation, particularly of oil and gas. The opening-up of the Arctic is likely to focus attention on the region's governance arrangements, but, despite challenges, current arrangements are likely to endure out to 2045. Large-scale military confrontation in either region is unlikely, but it is possible that some countries – depending on their internal politics – may seek to project power in the Arctic if they consider their interests in the region to be under threat. In Antarctica, the current governance arrangements are likely to endure out to 2045, but the Antarctic Treaty System could come under pressure to accommodate increased commercial exploitation within carefully managed bounds.

Space

Our reliance on space technology in a number of commercial and military areas will almost certainly increase out to 2045. Technological advances are likely to further reduce the cost of manufacturing and launching space vehicles, making space increasingly accessible to (and profitable for) countries, companies, organised crime and private individuals. As reliance on space grows, so could the impact of damage caused by deliberate attack, space weather and orbital collisions.

Key defence and security implications

Each section in GST 5 ends with a number of defence-related deductions. The following are the most important of those defence and security implications. Rather than attach any additional prioritisation to them, they are listed simply in the order in which they appear in the document.

- Technological developments will probably allow diasporas to remain more closely connected to their native countries. Consequently, issues from homelands are likely to be brought into host countries, and vice versa. Diasporas may also provide an impetus for governments to intervene - or refrain from interfering - in their citizens' countries of origin. Lack of integration of migrant groups could exacerbate social tensions. 3
- Increasing numbers of women are likely to have front-line combat roles in armed forces worldwide, mirrored by growing female participation in armed resistance movements and terrorist groups. 11
- Sexual violence will almost certainly continue to be a feature of conflict and state violence and, used as a weapon of war, has the potential to be a significant factor in instability. However, countries and their armed forces are likely to face greater international scrutiny and legislation against such activities. 11
- Failed and failing cities, in both developed and developing countries, could pose major security challenges (such as social unrest and even insurgencies) with the potential for country-wide repercussions. If more people live in urban areas, security and armed forces will almost certainly need to operate in this environment to a greater extent. Adversaries could range from government-controlled militaries to armed non-state groups with criminal or malign intent. 17
- Urbanisation concentrates populations, potentially making them more vulnerable to the effects of natural disasters, disease and deliberate acts of violence. With most urban areas in coastal regions, cities are likely to be particularly vulnerable to the effects of rising sea levels. 17
- Growing use of nuclear energy raises the possibility of fissile material being obtained by non-state actors as well as countries operating outside international laws, potentially causing security threats. 21
- Extreme weather events, such as flooding and droughts, are likely to increase in both frequency and intensity in a number of regions. Extreme events will almost certainly continue to cause widespread damage and loss of life, although our warning mechanisms, defences and ability to respond may also improve in the same timeframe. 31

- Armed and security forces, both at home and abroad, are likely to be more frequently tasked with providing humanitarian assistance and disaster relief, perhaps supporting indigenous responders. 31
- Greater reliance on automated technologies could provide scope for terrorists and criminals to disrupt the transport system through cyber attacks. 49
- As more of our work and social activities depend on interconnected information and communications networks – which may, in places, be extremely vulnerable to attack – there could be more opportunities for criminals and terrorists to have a greater impact on our day-to-day lives. 55
- An increasing number of devices capable of collecting sensor data could intensify levels of surveillance. Stealth vehicles may find it more difficult to remain hidden and the ability to prosecute covert operations, especially in urban environments, is likely to become more technically challenging. This is particularly significant given the probable increase in the size of urban areas, along with the growing use of surveillance to prevent crime. 55
- Unmanned systems are likely to have an increasing role in combat, potentially transforming the way that wars are fought. Military decision-making is likely to remain a human preserve, at least in western countries, but it is possible that the actual fighting will no longer be a solely human endeavour. 67
- The cost of unmanned systems is likely to fall, while the ease of manufacturing complex items rises, making unmanned systems much more widespread and harder to regulate. Criminal and terrorist groups are likely to find it easier to gain, hold and use unmanned capabilities. 67
- The expansion of alternative currencies may make it easier to transfer and retain funds anonymously and hence harder for governments to freeze criminals' assets or sanction rogue regimes. Criminal and terrorist groups may also find it easier to transfer funds between jurisdictions. 75
- The pressures of globalisation are likely to mean that individual countries will find it increasingly difficult to act unilaterally – most countries are likely to be less powerful. This could lead to a reduction in conflict. The state is still likely to have the most important voice in international affairs, but out to 2045 the private sector and non-state organisations are likely to become more influential. There is likely to be an increase in the use of private security companies by governments – interdependencies may strengthen, despite their largely separate motivations. 83
- Some augmentation of humans with embedded sensors and computing devices is likely to occur within the 2045 timeframe. This may provide advantages such as improved situational awareness, health monitoring, and the ability to modify physiological and psychological states to increase performance and enhance resilience. Mind-controlled machinery is likely to become much more sophisticated, with human brain-to-brain communication possible by 2045. 83

- The US and China are likely to have similarly sized defence budgets, potentially out-spending the rest of the world by 2045. India could have a defence budget equivalent to the EU's total spending on defence. 93
- Increasing real-terms equipment costs may mean that platforms become more expensive. Consequently, higher levels of defence spending may not lead to armed forces larger than today's. 93
- Although China is likely to surpass the US in terms of GDP, the US is still likely to remain, militarily, the most powerful country in the world. 101
- NATO is likely to remain the key security alliance for Northern American countries, although US (and possibly Canadian) commitments elsewhere in the world may mean that European countries will have to take on more of the burden of maintaining security in their region. 101
- There are a number of issues and treaties which may involve the US and China in armed conflict – with potentially dire consequences regionally and globally. 101
- NATO is likely to remain the key organisation for military crisis management, although its cohesion may be challenged by diverse threat perceptions, a US focus on Asia and internal disagreement on its global role. The Alliance could be reinvigorated by the need to band together to address a deteriorating security situation in Europe's near abroad. 117
- Internal terrorist threats are likely to continue in the Middle East and North Africa, as are attacks on other nations from groups based in the region. Although Al-Qaida has been damaged in recent years, Islamic fundamentalism will almost certainly continue to fuel terrorist networks out to 2045. 125
- In sub-Saharan Africa, the combined challenge of an increased population, demands on resources and the effects of climate change (particularly drought) on food and water supplies are likely to lead to tension, which could result in conflict. 133
- China's military is becoming more capable and has increasing global reach. By 2045, China's military capability may be close to matching that of the US, perhaps exceeding it in some areas. India's military capability is also likely to increase – but probably not to the point where it rivals that of China or the US by 2045. 147
- The East and South China Seas may be flashpoints for confrontation between China and the US and allied countries. Similarly Kashmir, the Korean Peninsula and the border between China and India are likely to be areas of tension. The risk of a major state-on-state conflict in the region cannot be ruled out. 147
- Commercial activity expansion in the Arctic Ocean may require extensive monitoring to safeguard Arctic countries' sovereignty. 155
- Increasing reliance on space-based technologies, particularly in developed countries, means that any large-scale disruption to satellites (such as solar superstorms) could have significant consequences for electricity distribution, communications, navigation, logistics and weather forecasts. 165

Methodology

Review of previous data

The Strategic Trends Programme has been running as a continuous research programme since 2001 and as a consequence there is a considerable body of material on trends and drivers. We began writing this fifth edition of Global Strategic Trends (GST 5) by reviewing our existing data to identify any inconsistencies and enduring trends. Themes, trends and drivers from editions one to four were mapped and compared. This produced an enduring trends map that showed similarities and some areas of contradiction.

Identifying gaps

In a parallel exercise, we engaged with a range of external contributors to explore the gaps in our existing research. We considered a number of new areas as a result.

Research topics

From the enduring trends map, output from our external engagement and a continuing process of in-house gap analysis, we identified nearly 30 research topics. These were a mix of new areas and existing themes that needed substantial updating. Researchers, from the Development, Concepts and Doctrine Centre's (DCDC) Futures Team, wider Defence or academia, wrote extensive essays on each topic, consulting widely and paying particular attention to defence and security implications.

Breakdown, analysis and mapping

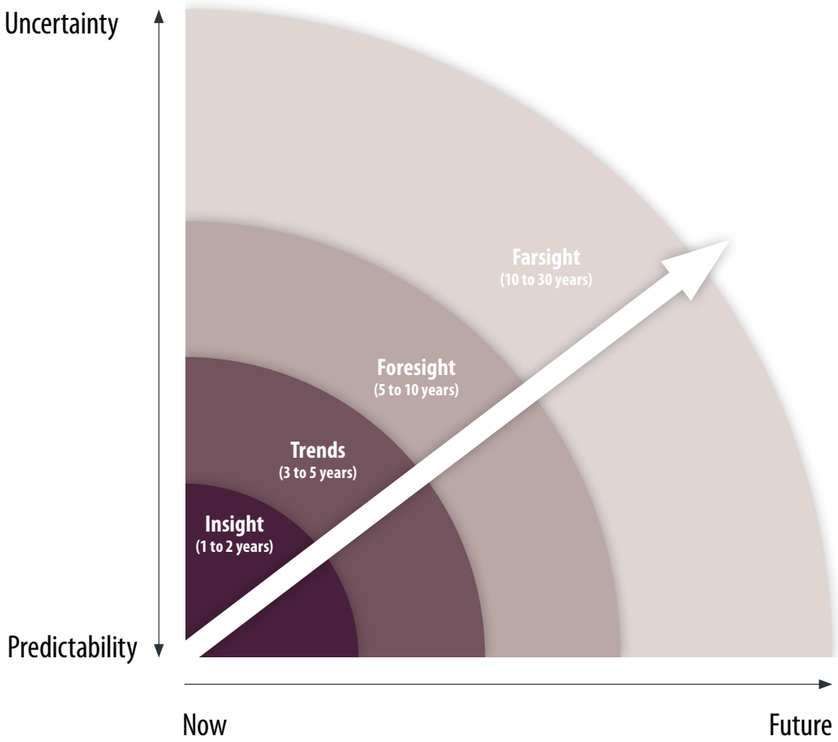
These essays were then analysed and mapped by DCDC's Defence Analysis and Research (DAR) Team to identify drivers, factors and trends. Ultimately, this produced a very detailed cluster map, drawing together both our previous work and new research. The map ordered themes and drivers into their top-level thematic areas, highlighting interactions and dependencies. How these relationships relate to one another helped us to understand the relevance and importance of our findings. The process also highlighted ideas that are based on assumptions or assertions that needed to be substantiated with additional evidence.

Draft sections for consultation

Short draft sections – based on either a theme or particular region – were sent for limited consultation across Government, industry, think-tanks and academia. Extensive engagement took place both in the UK and abroad, with visits to Brazil, China, France, India, NATO Allied Command Transformation, Qatar, Saudi Arabia, Singapore, South Africa, Sweden, the United Arab Emirates and the United States of America. Other international exchanges were conducted electronically, with Norway and Slovakia. We are grateful for the generous amounts of time and effort expended on reviewing these drafts which GST 5 has benefited from enormously. It was always our intention for GST 5 to be an inclusive and transparent, proactively engaging part of the Strategic Trends Programme, for wider benefit to policy- and decision-makers.

Consolidation, writing and editing

The final phase consisted of consolidating our work and incorporating feedback from the consultations, writing up our findings, adding scenarios to highlight key potential outcomes, including certain strategic shocks, and subjecting our work to a final round of peer review and editing.



A timeframe looking out 30 years means there is a huge degree of uncertainty in the world that we describe, which by its nature, is based on extrapolation and a degree of imagination.

Part 1

Thematic

This section brings together related trends and drivers under important themes. We describe the relationships between themes, trends and drivers and highlight the implications for defence and security.

Where a geographical relationship has been identified, the theme is cross-referenced to the appropriate regional section in Part 2.

Demography

The global population is likely to grow to between 8.3 and 10.4 billion by 2045, largely because of increasing life-expectancy, declining levels of child mortality and continuing high birth rates in many developing countries. Growth is not likely to be evenly distributed and will probably be slower in developed countries. Some, including Japan and a number of European countries, are likely to experience a decline in population. In developing countries, rapid population increase and urbanisation will probably challenge stability. Age and gender imbalances may exacerbate existing political and social tensions while a growing youth population, especially in the Middle East, Central Asia and sub-Saharan Africa, could provide a reservoir of disaffected young people. Conversely, if harnessed, they could provide a boost to their economies. Migration is likely to increase, with people moving within, and outside, their country of origin to seek work or to escape the effects of climate change.

Global population growth

The current world population of around 7.2 billion is expected to increase by almost one billion in the next 12 years and reach between 8.3 and 10.4 billion by 2045.[1] Driving factors for such an increase are a decline in infectious diseases, high birth rates in the developing world, improving maternal and neonatal health, improved sanitation and declining under-five mortality. Most of the population growth will probably occur, as it does today, in developing countries (mainly in sub-Saharan Africa), while the population in developed countries is likely to remain largely unchanged at around 1.3 billion. Developing regions are likely to account for approximately 97% of global population growth by 2050, with 38% taking place in the least developed countries. Africa is likely to account for 49% of global population growth by 2050. Population increases in poor areas may magnify existing poverty, generating an unsustainable demand for public services (for example, education, health and sanitation), unless there is a parallel increase in economic development. Conflicts over scarce resources are possible and could be an obstacle to development where it is most needed.

In most developed countries, birth rates have declined due to changes in attitude and way of life – the most important of which is an increase in the status of women.[2] Some countries have seen a recent increase in birth rates, although this is likely to be a temporary phenomenon. Overall, global birth rates halved between 1950 and 2010, dropping from 5 to 2.5 per woman,[3] and are likely to continue to decline. Newly-industrialising

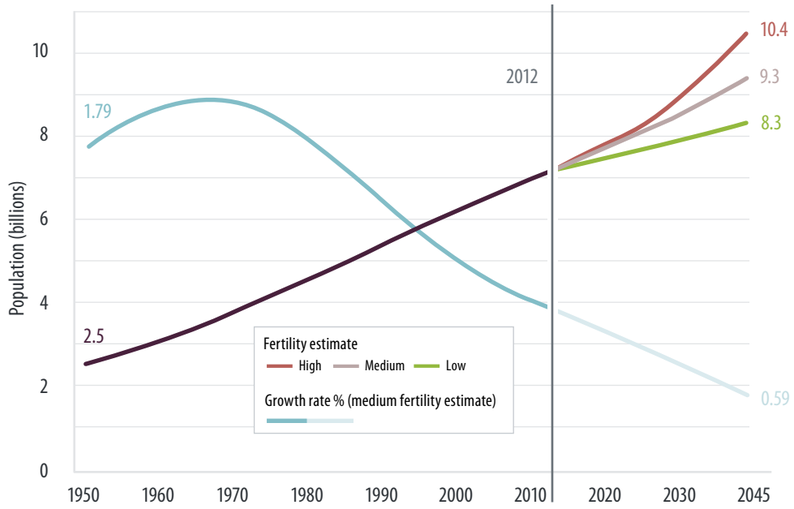
"Most of the population growth will probably occur, as it does today, in developing countries."

1 Global population is expected to reach 8.323 (if there is a low birth rate), 9.308 (if there is a medium birth rate) or 10.352 billion (if there is a high birth rate) by 2045. This forecast is drawn from UN (2012) 'World Population Prospects: The 2012 Revision', United Nations Department for Economic and Social Affairs hereafter referred to as UN WPP, available at http://esa.un.org/wpp/unpp/panel_population.htm

2 Population Bulletin of the UN (2002), 'Completing the Fertility Transition'

3 UN Department of Economic and Social Affairs (2010), 'The World's Women 2010: Trends and Statistics', available at http://unstats.un.org/unsd/demographic/products/Worldswomen/WW_full%20report_color.pdf

A growing population and a declining growth rate



Source: UN (2012), 'World Population Prospects: The 2012 Revision'

"Imbalances across regions and countries are likely to exacerbate existing political and social tensions."

countries in east and south eastern Asia have experienced reducing numbers of children per woman and a resulting decrease in the ratio of productive workers to dependents. These factors have contributed to their vigorous economic growth, and are likely to be a model that others seek to emulate.

Methods to slow population growth vary, as do their success. Mandated measures such as China's 'one child' policy have created long-term problems, such as a significant gender imbalance. Other approaches, however, show that it is possible to slow population growth with popular consent.[4] For example, sex education, access to contraception, reducing child mortality (negating the need for large families to ensure survival of family lines), and encouraged emigration policies have all helped to reduce growth rates. In many societies, bearing children grants a woman status in her community, but increasing female literacy and employment, as well as improvements in contraceptive technology and availability, are changing such cultural attitudes.[5] Women are becoming more empowered without needing to have several children.

Age and gender imbalances

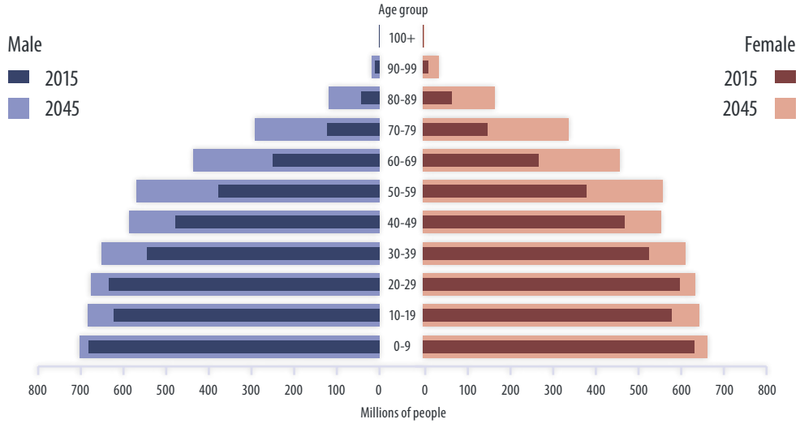
Imbalances across regions and countries are likely to exacerbate existing political and social tensions. The global median age is increasing (although the rate of increase is slower in developing countries) with those aged 60 or over comprising the fastest growing population age-group. Indeed, by 2045, 750 million people are likely to be over 65 years old.[6] For those countries with increasingly elderly populations, requirements such as public pensions, health services and long-term care are likely to be ever-more pressing – priorities which could reduce defence

4 Bangladesh is a good example of a society that has managed to reduce its high birth rates on a voluntarily basis.

5 Montgomery, K. (2009), 'The Demographic Transition'

6 Christine Lagarde (2014), 'A New Multilateralism for the 21st Century: The Richard Dimbleby Lecture'

Global population by ten-year age group and sex



Source: UN (2012), 'World Population Prospects: The 2012 Revision'

spending in most affected countries.[7] Some developing countries do not provide welfare and will not be directly affected by this trend. A declining working population coupled with increasing welfare costs are likely to lead to the retirement age increasing (as has happened in some developed countries). For some governments, a rising welfare burden is likely to lead to them re-evaluating how they provide social welfare. In societies with an ageing working population, older people are likely to hold an increased proportion of positions with authority and influence which, if not managed effectively, could disenfranchise the younger generation. Compounding this, young people may feel frustrated at the increasing cost of supporting a growing elderly population, particularly if they believe they have been disadvantaged by their elders.

Women are likely to still represent 55% of the world's population in 2045 and current gender imbalances in some areas are not anticipated to change significantly in this time. Some Asian countries are likely to continue to experience an uneven male to female population balance out to 2045, due to sex-selective abortions, child abandonment and diseases which disproportionately affect girls. For example, due to its demographic legacy, China may have 48 million more men than women by 2045,[8] potentially exacerbating gender imbalances in receiving countries if Chinese emigration increases. Increasing numbers of young men may be frustrated at being unable to find a wife and could lack the stability that a family life provides. Male-dominated societies also tend to be more authoritarian and violent. Studies monitoring the level of violence exhibited by states during

7 ISS (2013), 'Enabling the Future – European Military Capabilities', available at http://www.iss.europa.eu/uploads/media/Report_16.pdf

Alternative outcome:

Care costs

Ageing populations and increased dependency ratios may create funding pressures, particularly in developed countries. However, advances in healthcare and changes in education methods may see the cost of providing these services fall, as people become healthier, work longer and education becomes de-centralised.

8 UN WPP, *op. cit.* Figures based on medium birth rate for China at 2045.

The proportion of young adults is likely to grow most rapidly in sub-Saharan Africa

"If managed effectively, a high proportion of working age adults could provide countries with an economic boost."

international crises show that the severity of violence decreases as domestic gender equality increases.[9]

Globally, there are already three billion people under the age of 25, and this group is likely to increase.[10] The proportion of young adults is likely to grow most rapidly in sub-Saharan Africa, but there are also likely to be significant rises in Central and Southern Asia. In Middle Eastern countries, the proportion of young adults will probably reach its peak during the coming decade and by 2045 the majority of the population is likely to be between the ages of 15 and 59.[11] If managed effectively, a high proportion of working age adults could provide countries with an economic boost, but if the rising expectations of young adults are not met, social unrest could follow. Avoiding unrest is likely to depend on effective governance together with positive and inclusive economic development. However, these conditions will probably only be met in a limited number of affected countries.

Migration

Migration is likely to increase or, at least, remain constant.[12] In 2005, 191 million people lived outside their country of origin. Today there are 232 million (this figure already exceeds our earlier assessment in the 4th edition of Global Strategic Trends).[13] Those countries attempting to limit immigration are likely to be only partially successful. In preceding decades, migration has been characterised by people moving from Asia and Africa to Northern America and Europe.

9 Caprioli, M. and Trumbore, P. F. (2003), 'Identifying 'Rogue' States and Testing their Interstate Conflict Behavior', available at http://lib.znate.ru/docs/index-124184.html

10 Lagarde, *op. cit.*

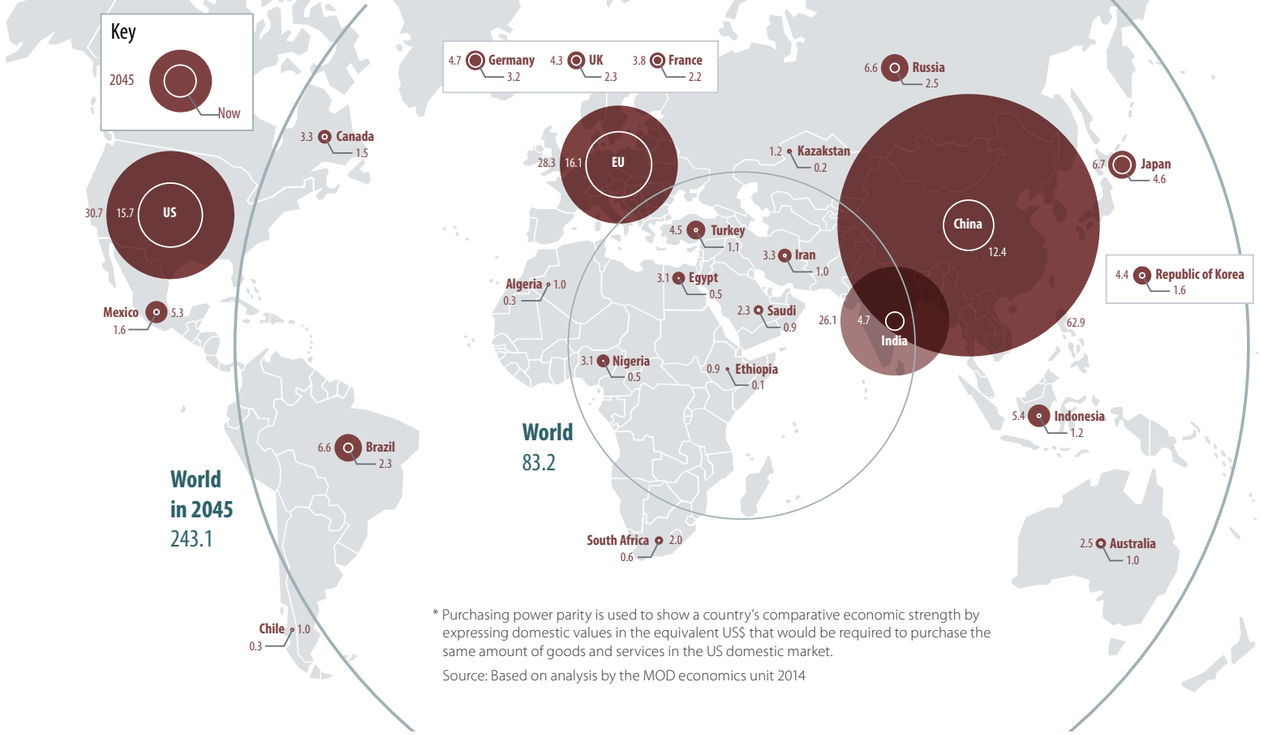
11 UN WPP, *op. cit.*

12 Statistics on migration from UN WPP, *op. cit.* and OECD (2009), 'The Future of International Migration to OECD Countries'

13 Figures from UN WPP, *op. cit.* show that the number of international migrants has already risen above 232 million (compared to GST 4's estimation that 230 million people would live outside their countries of origin by 2040).

Economic growth

Gross Domestic Product (adjusted for purchasing power parity)*, expressed in US$ trillion at 2012 values.



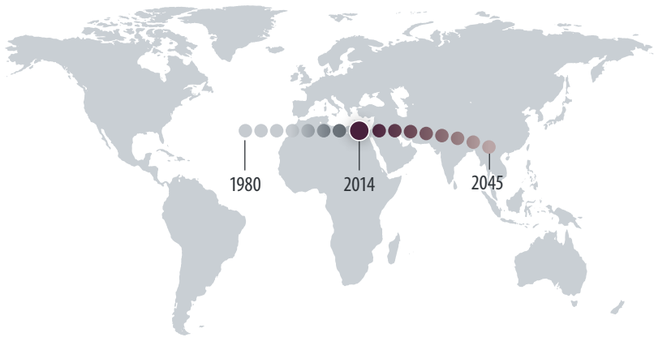
* Purchasing power parity is used to show a country's comparative economic strength by expressing domestic values in the equivalent US$ that would be required to purchase the same amount of goods and services in the US domestic market.

Source: Based on analysis by the MOD economics unit 2014

However, out to 2045, a growing number of migrants will probably move between and within Asia and Africa, with Asia becoming an increasingly important destination. Developed countries will almost certainly continue to attract significant numbers of migrants. As is the case now, most migrants are likely to be seeking work, although technological advances could lead to reducing demand for less skilled migrant workers and increasing demand for highly- and multi-skilled people. Temporary large displacements due to crises will probably continue to occur with high local impact – and the magnitude of such events is likely to be amplified by increased population density.

Global economic centre of gravity shifting

The steady rise of emerging economies in Asia will cause the world's economic centre of gravity – the average location of economic activity by GDP – to continue its move eastwards.



Source: Quah, D. (2011), 'The Global Economy's Shifting Centre of Gravity' (adapted by DCDC)

Asia's share of the growing consumer class could more than double **Chennai, India**

Climate change is likely to drive some people from areas that are particularly badly affected, although not everyone who wishes to leave is likely to be able to do so. Millions of people may be 'trapped' in vulnerable areas because of the high costs of migration, unable to raise the capital needed for moving away.[14]

During 2010-2050, the number of international migrants to developed countries is likely to be about 96 million, whereas the excess of deaths over births is projected to be 33 million, implying total net growth. The main estimated net receivers of migrants are likely to be the US, Canada, UK and Australia, while the main estimated senders are Bangladesh, China, India and Mexico.[15] Without immigration, the population in most developed countries is highly likely to reduce. Those developed countries that do see population growth, therefore, will almost certainly see an increase in the size and importance of their ethnic minority communities. While some ethnic groups are likely to integrate effectively and be economically successful, some are likely to be poorly integrated and economically disadvantaged – this may lead to tension and instability.[16] Some countries, for example Japan, are likely to face particular challenges. In light of Japan's long-standing sensitivity to the 'otherness' of *gaijin* (non-Japanese), immigration to Japan has been strikingly limited and assimilation of newcomers more so. Immigration, along with globalised communications, is likely to contribute to a growing cultural mix and complexity within countries. While the norms of receiving countries are likely to impact on migrants, the reverse may also be true. Technological developments are likely to allow diasporas to remain more closely connected to their native countries and hence they are likely to bring issues from their homeland into the host country, and vice versa. Diasporas may also provide an impetus for governments to intervene in their citizens' countries of origin – or to refrain from intervening.

14 Government Office for Science (2011), 'Migration and Global Environmental Change', available at http://www.bis.gov.uk/foresight/our-work/projects/published-projects/global-migration/reports-publications

15 UN WPP, *op. cit.*

16 See, for example, the European Commission series of cohesion reports.

A growing consumer class

A rapidly growing consumer class (those who spend more than ten US dollars a day) will almost certainly be a key driver of the global economy. By 2030, this group is likely to grow to more than five billion from two billion today,[17] while the proportion of consumers who are European and North American is likely to shrink from 50% today to just 22%. Rapid growth in many Asian countries, particularly China and India, is shifting the economic centre of gravity south and east. This looks likely to more than double Asia's share of the consumer class from its current level of 30% to around 64% by 2030.[18] As well as its economic importance, this group is likely to demand, and receive, more political influence. Typically, they are likely to be more mobile, place greater value on education, and be less accepting of the status quo. The likely growth of the consumer class may, however, mask a rise in global income inequality. Currently, 70% of the world's population lives in countries where disparities between the wealthiest and poorest have grown over the last 30 years.[19]

17 Lagarde, *op. cit.*

18 Rohde, D. (2012), 'The Swelling Middle', available at http://www.reuters.com/middle-class-infographic

19 Lagarde, *op. cit.*

Defence and security implications

- Areas with larger youth populations and poor governance are likely to suffer from instability, which could lead to unrest or conflict within the 2045 timeframe.
- Lack of integration of migrant groups could exacerbate social tensions.
- Technological developments will probably allow diasporas to remain more closely connected to their native countries. Consequently, issues from homelands are likely to be brought into host countries, and vice versa. Diasporas may also provide an impetus for governments to intervene – or refrain from interfering – in their citizens' countries of origin.

> *"Rapid growth in many Asian countries, particularly China and India, is shifting the economic centre of gravity south and east."*

Gender

Global gender equality and opportunity gaps will almost certainly continue in economic, social and political spheres out to 2045. Although women's autonomy is likely to gradually increase in most regions, entrenched gender disparities will probably remain as major drivers of poverty and insecurity. As is the case today, women are likely to have greater opportunities and autonomy in developed countries than elsewhere in the world, but are unlikely to achieve total parity with their male counterparts, particularly when social expectations inhibit the role of women in society. In some regions of the world, women's rights and feminist movements are likely to continue to face a 'backlash' from those with vested interests in maintaining the status quo.

Political decision-makers

The World Economic Forum reported that, of 110 countries it surveyed in 2006, 86% had improved their gender equality performance, while 14% had regressed.[1] Women's participation in politics has accelerated during the last decade with the proportion of women in national assemblies increasing from 11.6% in 1995 to 18.4% in 2008. Since 2004, the proportion of seats held by women in national parliaments has increased by 2% in developing as well as developed countries. If this trend continues, there would be an additional 10% of such seats by 2045. Trends indicate that, in countries with a quota system, such as those in Africa, formal parity is likely to be achieved more readily, although other measures also have a role to play in determining women's levels of political influence. Globally, women often lack the resources to access parliamentary level politics. They find barriers at selection and campaigning stages as well as prejudicial attitudes during elections. As a result, women at this highest level of politics are likely to continue to be predominantly drawn from elite societal groups. Barriers to entering 'formal' politics make it likely that women will continue to be comparatively better-represented in non-governmental organisations and civil society, playing an important role in peace- and state-building. This could take on particular significance if, as seems likely, such organisations take on an increasing role in meeting global aid and development needs.

Self-determination

Trends suggest that, particularly in the developing world, improvements in women's degree of autonomy over personal decisions – such as those relating to their employment, marriage and health – are likely to be slow. Such change may require alterations in social attitudes and 'ways of life' as well as legislation; and all segments of society may need to be involved. It can be difficult to quantify or measure gender inequality, but women's access to services such as contraception and health care can often be used as a proxy indicator for their degree of autonomy. For example, women with little say over their own reproductive autonomy are unlikely to be able to access family planning services. The rate of increase in women using reliable family

1 World Economic Forum (2013), 'The Global Gender Gap Report', available at http://www3.weforum.org/docs/WEF_GenderGap_Report_2013.pdf

"Women's participation in politics has accelerated during the last decade with the proportion of women in national assemblies increasing."

In low-income countries, the majority of women are involved in unpaid service

planning has stalled. Currently, more than 220 million women in developing countries who want to delay or avoid pregnancy lack access to effective methods of contraception and voluntary family planning services. Fewer than 20% of women in sub-Saharan Africa and barely one-third of women in South Asia use modern contraceptives. In the US, birth rates are increasing, which is ascribed to a decline in access to contraceptives, terminations and education in family planning. The unmet need for reliable birth-control methods is likely to continue out to 2045, with significant regional variations owing to a variety of social and cultural factors.

Employment

In most countries, women are less likely than men to be employed or looking actively for a job. Participation rates are highest in low-income countries—where a majority of women are active because they are involved in unpaid subsistence agriculture, although they are less involved in paid activities outside the household—and where few youth and adults are enrolled in education. Only 1% of the world's titled land is owned by women – a figure that has not changed for over ten years and is likely to remain roughly the same by 2045. It is estimated that women account for two thirds of the 1.4 billion people currently living in extreme poverty and make up 60% of the 572 million 'working poor' in the world. This general trend in economic activity is likely to remain in 2045.

In the past two decades, the overall numbers of females participating in the labour force have remained stable. Changes in gender norms and the roles of men and women have also begun to shift. However, women in developing countries still retain the 'double burden' of being responsible for (unpaid) domestic and care work, as well as taking on increasing roles in paid work outside the home. Gender inequalities in future employment are likely to centre on women not having equal access to higher-quality jobs, with commensurate pay and treatment. As a result of their lower educational attainment, domestic responsibilities and socially ascribed gender roles, women are more likely to work in informal employment. These characteristics are highly likely to persist by 2045.

Women in front-line military roles will become increasingly commonplace

Female Israeli Defence Force soldier

Women tend to be more active in the labour market in developed countries, especially those with extensive social protection coverage and in societies where part-time work is possible and accepted. Female wealth creation is likely to continue to increase within developed economies. In 2009, women controlled 27% of global wealth (roughly US$ 20.2 trillion)[2] but only 24% of senior management roles are filled by women. The UK's Equalities and Human Rights Commission estimates it will take 70 years at the current rate of progress to see an equal number of female and male directors of FTSE 100 companies.[3] In the UK, the gender pay gap stands at 15%, with women on average earning £5,000 less a year than their male counterparts. This disparity is even greater in part-time jobs, going up to 35%. Following the trend over the last 30 years, it is likely that (within the industrialised world) the gender gap in terms of pay is likely to reduce out to 2045.

Many of the world's defence and security organisations are likely to incorporate specific gender equality targets, and it is likely that by 2045 all formal barriers to women being involved in 'front-line' combat will be eliminated in most developed countries' armed forces. Mimicking changes in militaries, it is also probable that in 2045, armed resistance movements and terrorist groups will include greater numbers of women than at present.

Alternative outcome:

Rapid gender equality

By 2045, women's rights and status in society could improve at an even greater rate than current trends suggest, further reducing the gender gap. Increases in gender equality have historically had a substantial impact on poverty and the global economy, simply by improving women's access to birth control, education and increasing their opportunities.

"Female wealth creation is likely to continue to increase within developed economies but only 24% of senior management roles are filled by women."

2 The Boston Consulting Group (2010), 'Levelling the Playing Field', available at https://www.bcg.com/documents/file56704.pdf

3 Morse, F. (2014), 'International Women's Day 2014', available at http://www.independent.co.uk/news/world/international-womens-day-2014-the-shocking-statistics-that-show-why-it-is-still-so-important-9177211.html

The gender gap for primary school enrolments is closing

School girls in Cambodia

Education

Educational achievement is seen as a good predictor for future economic activity. Overall, the gender gap in primary education has shrunk, and global primary enrolments are now 48% for girls and 52% for boys. These statistics on enrolment may mask the numbers of children, often girls, who fail to complete their primary education because they are removed from school to marry early or to contribute to household income. While trends for girls and young women are improving, adult women still account for two-thirds of the more than 770 million illiterate adults in the world.[4] This has not changed significantly in relative terms over the past two decades and it is unclear whether it will improve significantly by 2045.[5]

Violence against women

Globally, around 35% of women have experienced physical or sexual assault, and as many as 38% of murders of women are committed by a husband or partner. Factors associated with perpetration of sexual violence include beliefs in family honour and sexual purity, ideologies of male sexual entitlement and weak legal sanctions for sexual violence. Violence is also likely to continue to be used as a weapon of war. Conservative estimates suggest that 20,000 to 50,000 women were raped during the 1992–1995 war in Bosnia and Herzegovina,[6] while approximately 250,000 to 500,000 women and girls were targeted in the 1994 Rwandan genocide.[7] Violence against women has tremendous costs, from greater health care expenses to losses in productivity, impacting national budgets and overall development.[8] In 2045, this global figure is likely to have only marginally declined compared to today. Sexual violence will almost certainly still impact negatively on a significant minority of women.

Human trafficking ensnares millions of women and girls in modern-day slavery. Women and girls represent 55% of the estimated 20.9 million victims of forced labour worldwide, and 98% of the estimated 4.5 million forced into sexual exploitation.[9] With further globalisation, there could be an increase in trafficking and slavery by 2045, although the trend may be mitigated by improved surveillance technology and international cooperation between police and security forces. If not addressed, an increase in trafficking and slavery could impact on regional and local stability, as it could enhance the criminal economy, thereby undermining the capability and authority of the state.

"There could be an increase in trafficking and slavery by 2045, although the trend may be mitigated by improved surveillance technology and international cooperation."

Defence and security implications

- Many of the world's defence and security organisations are likely to incorporate specific gender equality targets.
- Increasing numbers of women are likely to have front-line combat roles in armed forces worldwide, mirrored by growing number of females participating in armed resistance movements and terrorist groups.
- Sexual violence will almost certainly continue to be a feature of conflict and state violence. Used as a weapon of war, sexual violence can be a significant factor in instability. However, countries and their armed forces are likely to face greater international scrutiny and legislation against such activities.

4 OECD (2011), 'Shifting Wealth, Shifting Gender Relations?', available at http://www.oecd.org/dev/pgd/48619715.pdf

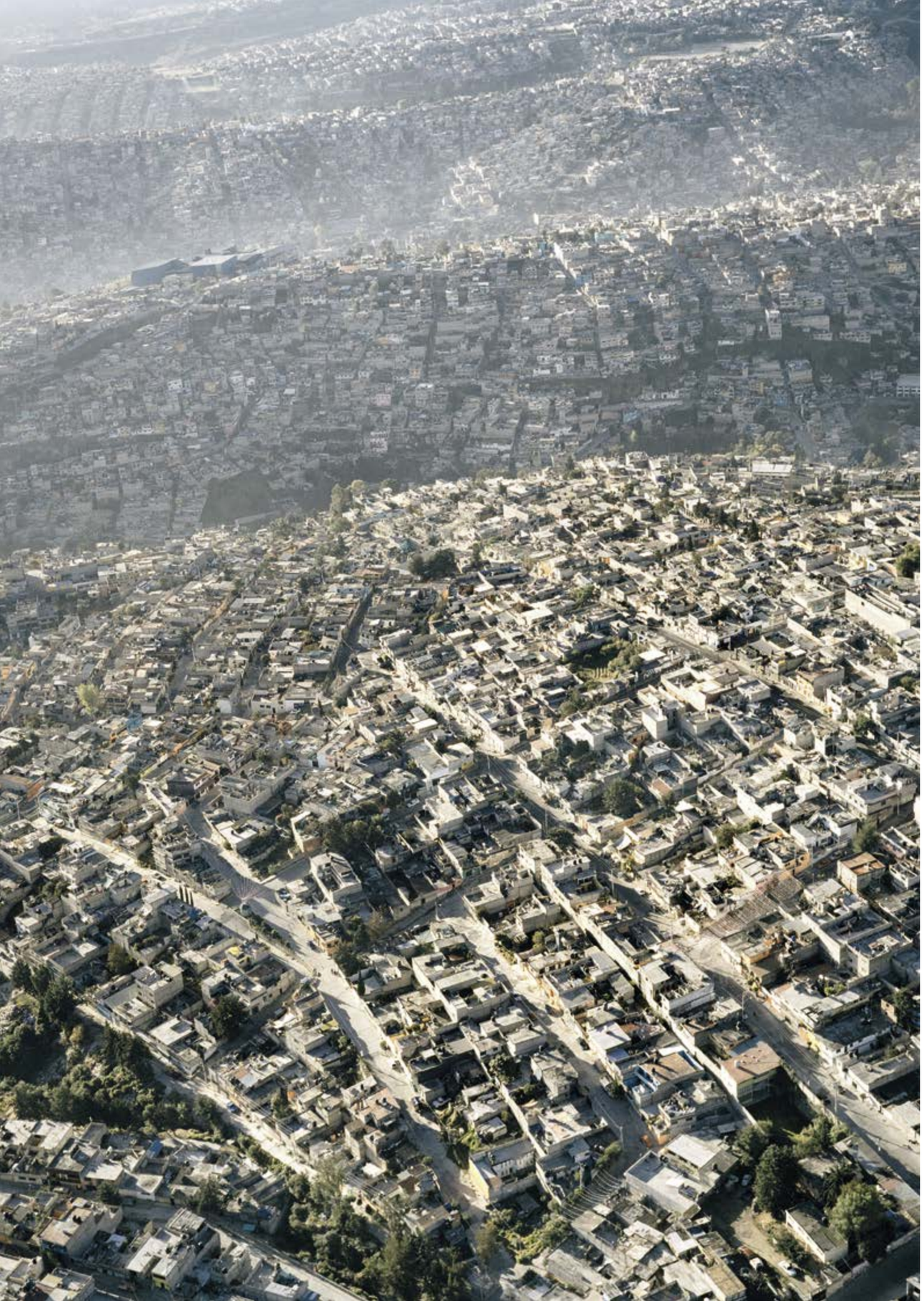
5 *Ibid.*

6 Based on reports by the Government of Bosnia and Herzegovina and the European Commission. Ward, J. (2002), 'Bosnia and Herzegovina, If Not Now, When?: Addressing Gender-based Violence in Refugee, Internally Displaced, and Post-Conflict Settings', cited in UNIFEM (2014), 'Facts and Figures on Peace and Security'

7 UN Special Rapporteur on the situation of human rights in Rwanda (1996), 'Report on the Situation of Human Rights in Rwanda'

8 UN Women (2013), 'Facts and Figures: Ending Violence Against Women', available at http://www.unwomen.org/en/what-we-do/ending-violence-against-women/facts-and-figures ; World Health Organisation (2013), 'Violence Against Women', available at http://www.who.int/mediacentre/factsheets/fs239/en/

9 International Labour Organization (2012), 'ILO Global Estimate of Forced Labour: Results and Methodology'



Urbanisation

With 70% of the global population likely to live in cities by 2045, urbanisation will be a particularly important theme in developing countries. Urbanisation is likely to enhance economic and social development, but – without mitigation measures – may also lead to pressure on infrastructure (and the environment) which could contribute to social tensions within the urban population. Urbanisation and the effects of climate change are likely to result in an increase in the magnitude of humanitarian crises, particularly since the majority of urban areas will almost certainly be either on, or near the coast, making these cities vulnerable to flooding.

From rural to urban

By 2045, the proportion of people living in urban areas is likely to have increased from a little over 50% to around 70% of the world's population.[1] Urbanisation will probably increase most rapidly in the developing world. Of the 23 cities expected to have ten million or more inhabitants by 2015, 19 are likely to be in developing countries. The greatest increases in urbanisation are likely to be in Asia, with between 250 and 300 million people likely to move from rural to urban areas over the next 15 years in China alone.[2] Although those who remain in rural areas may experience increased isolation as rural populations decline, technological advancements are likely to enable better communication and remote working. Managed successfully, urbanisation could stimulate economic growth.[3] In part, due to the exposure of new ideas and the accessibility of goods and services, it may also act as a spur for civil activism and improve the quality of life for many. While older cities are likely to have established links to resources, new cities may enjoy an infrastructural advantage – they will be able to build transport and communication networks suitable for modern vehicles and ways of working, without the constraints of historic buildings, narrow streets and obsolete infrastructure.

By 2045, there are likely to be around 280 megacities (cities with more than 20 million inhabitants[4]). Many of these could be agglomerations spanning administrative, and in some cases national, boundaries thereby driving integration and changing governance structures. Europe, for example, may have more than 20 major agglomerations by 2045 – the German Ruhr region, much of the Netherlands and Belgium could become a single gigantic urban area. The taxation rights of some major cities could make them major regional or international actors.

Urban challenges

Much of the rapid urban growth in developing countries, particularly in sub-Saharan Africa, is unlikely to be matched by investment in essential services and infrastructure. One billion people throughout the world already live in slums, lacking basic amenities – and

"Urbanisation could stimulate economic growth and may also act as a spur for civil activism and improve the quality of life for many."

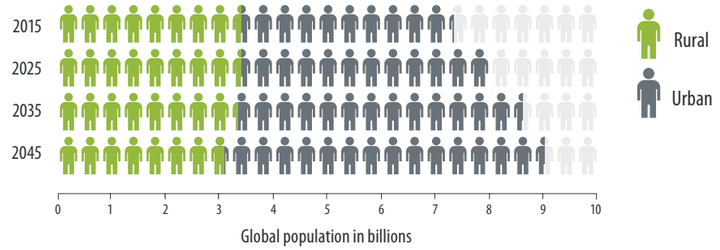
1 OECD (2012), 'Environmental Outlook to 2050'

2 Calculations by the Chinese Government as part of guidelines for infrastructural demands in the coming five year plan, specifically underlined by Premier Li Keqiang in his inauguration speech.

3 McKinsey Global Institute (2012), 'Urban World: Cities and the Rise of the Consuming Class'

4 UN Habitat (2011), 'State of the World's Cities Report 2010/2011'

A growing population living in the urban environment



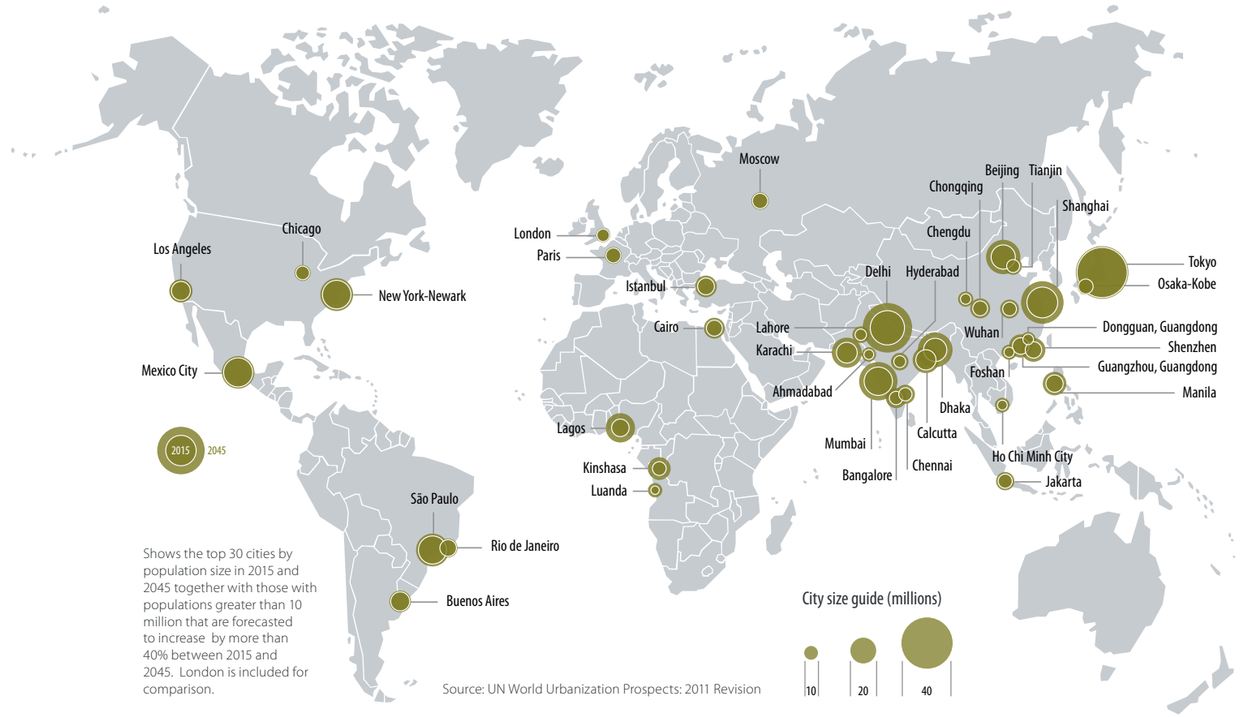
Source: UN 'World Urbanization Prospects: 2011 Revision'

there could be almost three billion people living in these conditions by 2045 if mitigating action is not taken.[5] Unless there is sufficient opportunity for bettering their lives, the urban poor are likely to become frustrated – and with increasing access to information, there is likely to be a growing awareness of inequality. If not dealt with effectively, this could lead to violent protest and possibly full-blown urban insurgencies. Similarly, cities in areas with population decline, or those with dysfunctional governance, will probably find it difficult to attract people and resources. These issues are likely to be exacerbated by demands for resources. In particular, urbanisation often results in increasing requirements for energy (particularly electricity), which could be a source of considerable tension unless it is provided in a sustainable way. Once people have access to energy, they are likely to always expect it. Some cities, in both developed and developing countries could fail (for example, becoming bankrupt or seeing a breakdown in law and order) – potentially becoming security issues. Correctly managed, though, urban growth could generate greater prosperity and higher tax revenues, potentially offsetting some of these more negative aspects.

Because of their concentrated populations, when disasters (whether natural or man-made) strike cities, large numbers of people are affected. Many of the biggest cities, a number of which are vital to the global economy, are situated in coastal regions which could face more extreme weather events and be vulnerable to rising sea-levels. Furthermore, because of inadequate sanitation, slums could be susceptible to communicable diseases – which could then spread globally because of increased connectivity between cities.

5 UN (2013), 'World Economic and Social Survey 2013', available at http://www.un.org/en/development/desa/policy/wess/wess_current/wess2013/WESS2013.pdf

Major centres of population



Shows the top 30 cities by population size in 2015 and 2045 together with those with populations greater than 10 million that are forecasted to increase by more than 40% between 2015 and 2045. London is included for comparison.

Source: UN World Urbanization Prospects: 2011 Revision

Defence and security implications

- Rapid urbanisation and inadequate socio-economic infrastructure are likely to increase the number and scale of densely populated slums. Such areas are likely to be more prone to social unrest.
- Failed and failing cities, in both developed and developing countries, could pose major security challenges (such as social unrest and even insurgencies) with the potential for country-wide repercussions. If more people live in urban areas, security and armed forces will almost certainly need to operate in this environment to a greater extent. Adversaries could range from government-controlled militaries to armed non-state groups with criminal or malign ideological intent.
- Urbanisation concentrates populations, potentially making them more vulnerable to the effects of natural disasters, disease and deliberate acts of violence. With most urban areas in coastal regions, cities are likely to be particularly vulnerable to the effects of rising sea levels.
- People living in slums could be more susceptible to communicable diseases, which could then spread globally as a result of increased connectivity between cities.

Resources

Demand for resources of all kinds is likely to increase out to 2045, as the world's population rises to around nine billion. While the demand for food will grow, some countries are likely to experience significant declines in agricultural productivity. Water shortages are likely to be particularly acute in many areas, exacerbated by increasing demand and climate change. In the 2045 timeframe, coal and hydrocarbons are likely to remain the most important sources of energy, with renewable and nuclear energy likely to make an increasing contribution.

Water

Even at current population levels, supply of fresh water is, arguably, insufficient.[1] Factors such as population growth, increasing demand from industry and agriculture, and reliance on unsustainable water sources (such as aquifers) are likely to mean that many people may not have reliable access to adequate supplies of water.[2] By 2045, global agricultural water consumption could increase by 19%, with global fresh water demands likely to grow by 55% in the same period.[3] Estimates of those suffering from water shortages today vary between 450 million[4] and more than 1.3 billion people.[5] Without mitigation, by 2045 or sooner, around 3.9 billion people – over 40% of the world's population – are likely to be experiencing water stress. This represents a significant increase on the estimated 2.6 billion people suffering water shortages in 2000.[6]

The poorest people often have extremely limited access to fresh water. Someone living in a slum may only be able to access about five to ten litres daily, while a middle- or high-income individual living in the same city may use about 50-150 litres per day. An estimated 2.2 million people die every year from diseases that cause diarrhoea because of inadequate water and sanitation.[7] This is still likely to be problematic by 2050, when 1.4 billion people (mainly living in developing countries) are unlikely to have basic sanitation.[8] Efforts to improve safe water supply and health-care access have succeeded in reducing deaths from diarrhoea, but these gains may be thwarted as the number of people living in slums increases, while environmental change places further stress on fresh water availability. However, there continues to be advances in water desalinisation technology, as well as activity to reduce water waste and

"By 2045 or sooner over 40% of the world's population are likely to be experiencing water stress."

1 Oxford Research Group (2011), 'Competition over Resources: Drivers of Insecurity and the Global South'

2 Wiltshire, A. *et al.* (2013), 'The Importance of Population, Climate Change and CO_2 Plant Physiological Forcing in Determining Future Global Water Stress'

3 OECD (2012), 'Environmental Outlook to 2050'

4 UN Environment Programme estimate.

5 Falkenmark, M. (1986), 'Fresh Water - Time for a Modified Approach'; Rockström, J., *et al.* (2009); 'Future Water Availability for Global Food Production: The Potential of Green Water for Increasing Resilience to Global Change'

6 Wiltshire, A. *et al.*, *op. cit.*; Arnell, N. (2004), 'Climate Change and Global Water Resources: SRES Emissions and Socio-Economic Scenarios'

7 WHO (2009), 'Water-related Diseases', available at http://www.who.int/water_sanitation_health/diseases/diarrhoea/en/

8 OECD, *op. cit.*

Meat consumption in Asia is increasing

improve water utility. Improvements in waste treatment and purification technologies offer hope that in the future more water could be reused or recycled.

A shortage of water could lead to countries (and communities within them) diverting water for their benefit to the detriment of others. Many water resources are shared by more than one country – 263 river basins and 269 aquifers are shared by two or more countries,[9] and 21 rivers and four aquifers cross the boundaries of more than five countries.[10] As demand for water intensifies, it could lead to conflict. Some experts argue that water scarcity drives closer cooperation[11] and, despite tensions, no modern state has ever declared war on another solely over water.[12] But there are a number of reasons why violent conflict over water may occur by 2045 or sooner. For example, global demand is likely to increase while supplies of fresh water dwindle, yet water management issues are likely to become increasingly complex. The effects of environmental and climate changes will also probably become more severe in many locations, potentially outweighing any beneficial consequences.

"There are a number of reasons why violent conflict over water may occur."

Food

By 2045, food production is predicted to have increased by nearly 70%, to feed a larger and more demanding population[13] – and it is possible that demand could outstrip supply. Some types of consumption are likely to grow particularly strongly. As affluence grows in the developing world, the demand for more protein-rich diets is also likely to increase. China, for example, has seen meat consumption increase by 63% between 1985 and 2009, and this trend seems likely to continue.[14] Pollution and soil erosion are likely to adversely affect agricultural land – some estimates assess that, globally, as much as 25% of agricultural land is already degraded.[15] Climate change will almost certainly have adverse effects on some agriculture, but may open up new areas for cultivation, with positive impacts on particular crops in certain regions. On balance, even though the quality of some areas is likely to have been degraded by 2045, the global arable land area is projected to remain relatively constant (estimates range from a 10% decrease to a 25% increase),[16] with some potential increases in crop productivity in the high latitudes, and decreases across the tropical regions.[17] Furthermore, warming, acidification and over-fishing also threaten to reduce the amount of food that can be harvested from the oceans.

Estimates of future food prices are highly varied and may be more volatile, although most projections indicate a general increase.[18] Analysis by the International Food Policy Research Institute suggests that average prices of many staple grains could rise by 30% even in the most optimistic scenario.[19] Disruption, and possibly congestion, of global trade routes may lead to sharp increases in food prices – particularly in those countries dependent on food imports. When the effects of climate change are taken into account, the price increase above present levels could be as much as 100%.[20] Inflation of food prices could also be driven by a shortage of arable land, particularly in Africa and developing parts of South and East Asia. A number of factors are likely to put pressure on the availability of land for cultivation, such as: the rapid development of bio-fuels; the effects of climate change; dwindling water supplies; increasing demand to use land for industrial and urban growth. Set against this, transferring current technologies and closing existing productivity gaps by developing new measures to maximise yields could be important in ensuring productivity growth keeps pace with demand. Developments such as genetically modified crops, laboratory-cultured meat, improved agricultural techniques and recent developments in nitrogen fixing from the air,[21] may also increase productivity while lowering the environmental impact of agriculture. These advances may mean that forecasted food prices could be lower than expected, or even cheaper than today. Historical evidence shows that higher food prices cause a jump in hunger levels. For example, during the 2008 food crisis, the number of hungry people in the world increased by 40 million, primarily due to increased food prices. It is likely that by 2045 food shortages will increase the number of children under the age of five who are undernourished by around 20-25 million,[22] while the global malnourished population could increase by around 49 million.[23]

"Average prices of many staple grains could rise by 30% even in the most optimistic scenario."

9 Cooley, H. *et al.* (2009), 'Understanding and Reducing the Risks of Climate Change for Transboundary Water', available at http://www.pacinst.org/reports/transboundary_waters/transboundary_water_and_climate_report.pdf

10 *Ibid.*

11 Allouche, J. (2010), 'The Sustainability and Resilience of Global Water and Food Systems: Political Analysis of the Interplay Between Security, Resource Scarcity, Political Systems and Global Trade'

12 Pandya, M. (2009), 'Troubled Waters: Climate Change, Hydropolitics and Transboundary Resources'

13 UN Food and Agriculture Organisation (2009), 'How to Feed the World in 2050', available at http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

14 Australian Department of Agriculture (2012), 'Food Consumption Trends in China'

15 Re|Source Conference (2012), 'The Challenge of Feeding 9–10 Billion People Equitably and Sustainably', available at http://www.reversethefuture.org/media/medialibrary/2012/07/Professor_Charles_Godfray_-_ReSource_2012_Food_Briefing.pdf

16 Lobell, D. B., Baldos, U. L. C., and Hertel, T. W. (2013), 'Climate Adaptation as Mitigation: the Case of Agricultural Investments'; Zhang, X. and Cai, X. (2011), 'Climate Change Impacts on Global Land Availability'

17 Fischlin, A. *et al.* (2007), 'Ecosystems, Their Properties, Goods, and Services'; Müller, C. *et al.* (2010), 'Climate Change Impacts on Agricultural Yields', Knox, J. *et al.* (2012), 'Climate change impacts on crop productivity in Africa and South Asia'

18 Lobell, D. B. *et al., op. cit.;* Nelson, G. C. *et al.* (2009), 'Climate Change: Impacts on Agriculture and Costs of Adaptation'; Nelson, G. C., *et al.* (2013), 'Agriculture and Climate Change in Global Scenarios: Why Don't the Models Agree?'

19 Nelson, G. C. *et al.* (2010), 'Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options', available at http://www.ifpri.org/sites/default/files/publications/rr172.pdf

20 *Ibid.*

21 Phys.org (2013), 'World Changing Technology Enables Crops to Take Nitrogen from the Air', available at http://phys.org/news/2013-07-world-technology-enables-crops-nitrogen.html#ajTabs

22 Nelson, G. C.,*et al.* (2009), *op. cit.*

23 Baldos, U. L. C. and Hertel, T. W. (2013), 'Global Food Security in 2050: The Role of Agricultural Productivity and Climate Change'

Energy

A growing global population will almost certainly increase its demand for energy. Most analysts expect that demand could more than double by 2045.[24] The amount of power derived from nuclear[25] and renewable energy is likely to increase out to 2045, but may remain less significant than coal and hydrocarbons. Growing use of nuclear energy raises the possibility of fissile material being obtained by non-state actors as well as states operating outside international laws, potentially causing security threats. While there could be significant breakthroughs in developing novel energy sources or making existing technologies suitable for the mass market (thorium reactors or fuel cells, for example) there is little evidence to suggest that this will occur by 2045. Furthermore, while fossil fuels remain relatively cheap, there is little incentive to fund the development of new energy sources.

"Much of the future demand for electricity will probably originate in developing countries, although it may be extremely difficult to meet this growth in demand."

Demand for electricity is also likely to increase.[26] Regardless of the source, producing electricity consumes a significant amount of primary energy (though this can be limited to the manufacturing stage – for example, producing solar panels) and energy is also lost in transmission, and sometimes through theft. However, technological developments are likely to increase the efficiency of electricity generation by 2045. Much of the future demand for electricity will probably originate in developing countries, although it may be extremely difficult to meet this growth in demand without investing significantly in power generation capacity and the necessary distribution infrastructure. It is unclear whether such investments will be made. In developing countries, particularly those in Africa, creating economically viable distribution networks will probably require cooperation between countries. The interconnectedness of energy markets and transportation networks may also mean that current choke-points become more congested. The consequences of blockages in areas such as the Panama Canal, Straits of Hormuz and the Malacca Straits could be felt far beyond their point of origin.

24 International Energy Agency (2012), 'World Energy Outlook'; Energy Information Administration (2012), 'International Energy Outlook'; Exxon Mobil (2012), 'Outlook to 2040'

25 There are currently 435 operable civil nuclear power reactors around the world, with a further 67 under construction. See World Nuclear Association (undated), 'Number of Nuclear Reactors', available at http://www.world-nuclear.org/Nuclear-Basics/Global-number-of-nuclear-reactors/

26 Exxon Mobil (2013), 'The Outlook for Energy: A View to 2040', available at http://cdn.exxonmobil.com/~/media/Reports/Outlook%20For%20Energy/2014/2014-Outlook-for-Energy.pdf

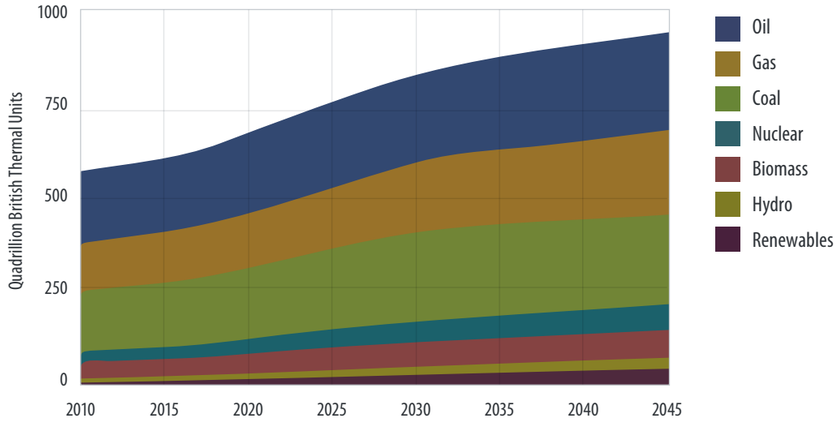
Scenario:

Breakthrough in alternative energy

It is possible that, by 2045, work on new methods of generating energy will bear fruit, such as harnessing the Sun's energy by splitting seawater into hydrogen and oxygen. If such processes could be industrialised, without producing significant amounts of pollution, near-limitless amounts of extremely cheap energy could be generated. Without the constraints of cost or pollution, heat and light could be freely available to all of the world's people, with a number of beneficial consequences.

For example, if energy cost was no longer an object, desalinated water could be transported via pipelines to irrigate much of the Sahara, massively increasing the continent's arable land and potentially ending hunger. Similarly, desalinisation plants could resolve the probable crisis in water supply.

Global energy demand by source



Source : US EIA 'International Energy Outlook 2013'

Energy storage

Power sources such as wind, tidal and solar are intermittent, providing energy when conditions are right rather than when needed. This mismatch between availability and demand is one of the main obstacles limiting the proportion of energy generated from renewable sources[27] and perpetuating reliance on conventional methods of power generation. Improving the ability to store energy would make using renewable energy sources much more practical. While a number of means of storing energy are available, they suffer limitations that prevent their use on a global scale. For example, storing water to produce hydropower has limited capacity for expansion, and conventional batteries are too expensive for storing vast amounts of energy.[28] New approaches such as adopting organic materials like wood and newly discovered liquids to produce large-scale batteries could provide affordable and environmentally sustainable storage.[29] Such systems are highly likely to be available and in common use by 2045, making it possible to rely more on renewable energy and reduce the number of conventional power stations needed to meet the growing demand for energy. International interest in energy storage has led governments in Europe, the US, Japan and elsewhere to provide funding or make regulatory changes to encourage innovation.

Growing US energy independence [30]

A key change to the global energy market by 2045 is likely to be growing US energy independence, driven by recently adopted novel oil and shale gas production techniques such as 'fracking'. If the current increases in production continue, the US looks set to become the world's number one oil producer by around 2020 and a net exporter by 2030,

"Adopting organic materials and newly discovered liquids could provide affordable and environmentally sustainable [energy] storage."

27 Energy Research Partnership, collated by Workman, M. (2013), 'DCDC Technology Review for Shale Gas, CCS and Energy Storage'

28 Pumped-storage hydropower typically takes advantage of natural topography and accounts for more than 99% of bulk storage capacity. See The Economist (2012), 'Energy Storage: Packing Some Power', available at http://www.economist.com/node/2154

29 The Economist (2013), 'Battery technology: A Pile of Wood'; Huskinson, B. *et al.* (2014), 'A Metal-Free Organic–Inorganic Aqueous Flow Battery', available at http://www.nature.com/nature/journal/v505/n7482/full/nature12909.html

30 'Energy independence' refers to a country meeting its total energy requirement from all sources at its disposal, including imports and trades. This is not the same as 'energy self-sufficiency', a term often taken to mean that no imports or trade are required to meet a country's energy needs.

"The cost of energy to US-based manufacturers could return to pre-1970s prices, providing them with significant savings."

dramatically altering the energy production industry.[31] Exploiting and exporting unconventional oil and gas, however, is not without its challenges. The main sources of US shale gas and oil are far away from existing pipeline infrastructure, and refineries are designed to process the heavier crude oil from the Middle East. Furthermore, if returns on investment for oil and gas producers are insufficient, the rate of development may slow.[32] However, if US electricity providers are able to accelerate their shift from coal or oil to natural gas, the cost of energy to US-based manufacturers could return to pre-1970s prices, providing them with significant savings.[33] Consumers should also benefit through lower energy bills, leaving them more money for discretionary purchases. Because natural gas burns more cleanly than coal, there may also be environmental benefits. Low energy costs and a healthy consumer market could make the US an attractive location for manufacturers and other energy-intensive industries, providing a significant boost to the US economy. The share of electricity generated by burning coal in the US has fallen to its smallest in nearly 40 years amid historically low natural gas prices.[34] This US shift away from coal is likely to continue to affect global coal prices with implications for coal-exporting countries.

A reduced requirement for Middle Eastern oil (coupled with a shift in the Middle Eastern markets toward Asia) could call the US commitment to the Middle East into question. However, US involvement in the Middle East is unlikely to alter significantly as the region will almost certainly continue to have a significant bearing on global stability and security. US interests in maintaining lines of communication are likely to continue out to 2045. Other powers (particularly China, Europe and India) are also likely to be vying for influence and the US has long standing commitments to countries in the region – not least Gulf Cooperation Council allies and Israel. Quite apart from political concerns, the oil market is genuinely global. The price of oil in the Middle East will almost certainly affect the price of oil produced in the US and vice versa; meaning that any serious disruption to the Middle East (or other major oil producing regions) could also impact upon the US economically.

Critical and novel materials

The availability of natural resources such as rare earth elements (a group of 17 metals often vital for many technologically advanced products)[35] and other critical materials are likely to remain key to enabling technological progress. However, they are often only available from a limited number of sources. Although physical depletion is not generally considered a threat to supply, other factors such as access, environmental impact and ethical issues (such as exploitative mining practices) are concerns.[36]

The discovery of alternative materials offering improved efficiency, reliability and longevity is likely to reduce demand for some traditional materials (although it may lead to increases in others). Some examples of these new materials and their potential applications are described on the next page.

31 International Energy Agency (2012), 'World Energy Outlook 2012', available at http://www.iea.org/publications/freepublications/publication/English.pdf

32 Joint Research Centre (2012), 'A Report to the Energy Security Unit of the Joint Research Centre of the European Commission'

33 Christopher J. Wolfe, Chief Investment Officer of the Private Banking and Investment Group at Merrill Lynch, "We could end up with the cost of energy to US manufacturers returning to what it was in the 1970s or even the '60s, adjusted for inflation." Quoted in Merrill Lynch (2013) 'A Transforming World', available at http://wealthmanagement.ml.com/publish/content/application/pdf/GWMOL/AR9D50CF-MLWM.pdf

34 Teranzono, E. (2012) 'US Power Groups Switch to Gas Hits Coal', available at http://www.ft.com/cms/s/0/4924ea34-afef-11e1-b737-00144feabdc0.html?siteedition=uk#axzz2ravy9egj

35 British Geological Survey (2013), 'World Mineral Statistics Database'

36 Department for Environment, Food and Rural Affairs (2012), 'Resource Security Action Plan: Making the Most of Valuable Materials', available at https://www.gov.uk/government/publications/resource-security-action-plan-making-the-most-of-valuable-materials

Material	Potential applications
Miniaturisation	
DNA nanotechnology to fabricate nano-scale devices. The self-assembly mechanism of DNA could be harnessed to fabricate mechanical, electrical and optical devices and circuits that may be ten times smaller than current technology allows.	Significant expansion of the capabilities of computers, such as improved processing power; better ability to synthesise materials by design; the development of advanced therapeutic and drug delivery systems; and ultimately, the development of nanobots.
New developments in piezoelectric materials (materials that turn kinetic energy into electrical energy) could allow devices without batteries to run on power harvested from vibrations and operate at more extreme temperatures.	Constructing devices able to operate in normally unreachable or unsafe locations, such as the monitoring environmental conditions in places too dangerous for humans.
Replacements for traditional materials	
Micro-alloys such as palladium-based metallic glass with a strength and toughness greater than any known material.	May be used in small-scale components, leading to better-constructed aircraft and spacecraft.
Graphene paper. Flexible and inexpensive to produce, and around ten times stronger than steel.	Replacements for a range of conventional and existing composite structural materials, far stronger than those available today. Could also support miniaturisation and sensors with greater sensitivity and accuracy.
Responsive materials	
Magnetic shape-memory alloys. Materials that change shape and mechanical properties when a magnetic field is applied.	Ultra-efficient engine valves that open and close automatically; positioning tools for microsurgical procedures; sensors for detecting environmental contaminants; and less toxic batteries. Applications likely to be limited to a small scale, due to the challenge of integrating the required high magnetic field actuation system.
Self-repairing metal. Metal that responds to damage by 'healing' itself, such as nickel super-alloys with designed-in defects that allow cracks to repair themselves under normal loading conditions.	Better structural materials that could be used in turbine blades, giving better resistance to fatigue.
Information-providing protective coatings. Chemical reactions that are triggered by various failure mechanisms, resulting in a change of visual appearance to indicate when maintenance or repair is required.	Active corrosion protection systems; coatings which indicate exposure to chemical or biological agents; coatings which indicate aging.
Metamaterials *Artificial materials engineered to exhibit properties that only rarely occur naturally*	
Nanospheres. A transparent material made of self-assembling nanospheres that is the stiffest organic material ever created, surpassing the properties of stainless steel and even Kevlar.	Revolutionary improvements in body armour, with the potential for new ways to customise products, such as printed body armour. A component for strengthening existing metals and composites; creating medical implants.
Ultra-lightweight and ultra-absorbent materials such as highly-porous carbon constructs one-sixth the density of air and highly absorbent.	Current materials used for cleaning up oil spills absorb around ten times their weight in oil, but new materials show potential to handle 900 times their weight in oil with very high rates of absorption. Capture and transport aerosols such as pollutants and water vapour.
Jelly-forming polymers so effective that a kilogramme of the compound could turn the water within an Olympic-sized swimming pool into jelly.	Treating wounds; altering or denying access to waterways.
Programmable matter. Materials that can be programmed to alter themselves at the molecular level into various shapes and then disassemble to form entirely new ones.	Compounds that can reform the shape of components in real-time, similar to holograms, could allow the remote projection of a replica of a person or object, or enable robots to change size (and perhaps even state of matter) to navigate narrow passages or around obstacles.

"Rising demand for rare earth elements could continue to motivate countries in trying to develop or secure their own sources of supply."

Resource protectionism

Increased demand for critical materials – which could include oil and water – has seen governments adopt protectionist measures to boost revenues and secure access to resources. These practices are likely to endure out to 2045. Anti-competitive behaviours such as expropriation of foreign companies, export restrictions, cartel-pricing behaviour, 'land acquisition' or high taxation are forms of resource nationalism designed to restrict international supply. For example, potash (used in agriculture) is increasingly subject to government-to-government trade deals rather than being traded on the open market. Rising demand for, and concerns over, access to rare earth elements could continue to motivate countries in trying to develop or secure their own sources of supply, bypassing international markets. While running out of these materials is unlikely within the 2045 timeframe, reliability of supply could be an issue because they are only mined in a very small number of countries (for example, China produces 86% of all rare earth elements). If one of those countries restricted supply, it would be likely to have a significant impact on availability and price.[37] However, such action is not without its costs. Unpredictable and retro-active policy changes to protect resources can, for example, lead to a drying up of foreign investment or customers.

Resource inequality

Inequitable distribution of resources including food, water, energy and materials will almost certainly endure out to 2045, both between countries and within them. Plentiful supplies of food and water are usually beneficial. However, plentiful supplies of hydrocarbons and minerals can be destabilising – especially in countries with authoritarian or fragile governance. In such countries, profits from mineral and hydrocarbon extraction are often (through corruption) concentrated in the hands of elites. This can result in grievances, leading to instability and potentially violent conflict. Inequitable availability of food and water, particularly in those countries suffering from shortages, is also likely to lead to instability and violence.

37 Ernst and Young identified resource nationalism as the top risk in their assessment of 'Business Risks Facing Mining and Metals 2011–2012', available at http://www.ey.com/Publication/vwLUAssets/Business_risks_facing_mining_and_metals_2011-012/$File/Metal_Mining_paper_02Aug11_lowres.pdf. This represented a move from fourth highest risk, behind skills and cost, to the number one risk in 2012 – an assessment which has held in their updated report. See also Lee, B. (2012), 'Resources Futures', available at http://www.chathamhouse.org/publications/papers/view/187947

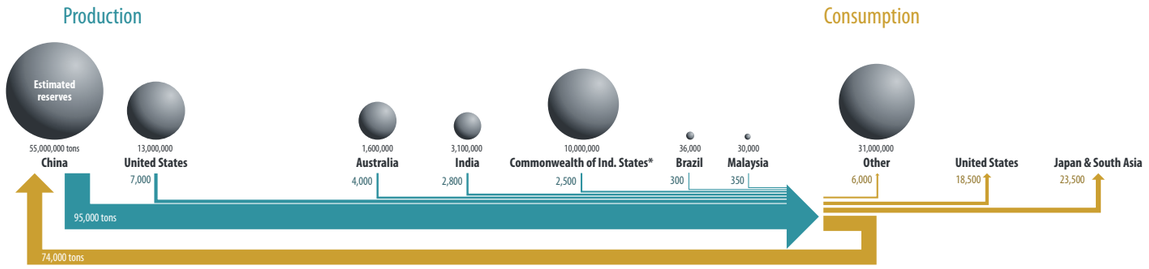
Defence and security implications

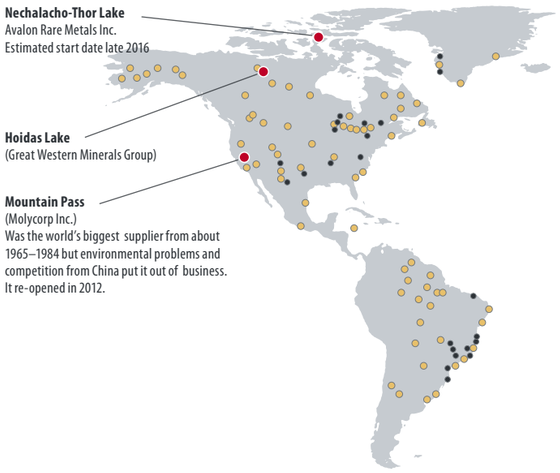
- Competition over some resources is likely to intensify and exacerbate existing political and security tensions, potentially acting as a catalyst for intra- and inter-state conflict.
- Demand for food may outstrip supply, leading to a rise in costs. Food shortages could lead to sharp price spikes, which could result in instability in those areas unable to absorb the increase.
- Climate change could contribute to increasing incidences of crop failure, potentially causing disruption to global food supplies.
- Growing use of nuclear energy raises the possibility of fissile material being obtained by non-state actors as well as countries operating outside international laws, potentially causing security threats.
- A reduced requirement for Middle Eastern oil by the US, coupled with a shift in the Middle Eastern markets toward Asia, could bring the US commitment to defence of Middle East export routes into question. However, US involvement in the Arabian Gulf is unlikely to alter significantly. But the US may look to other countries, including China and the EU, to play a greater role in security provision in the Middle East.

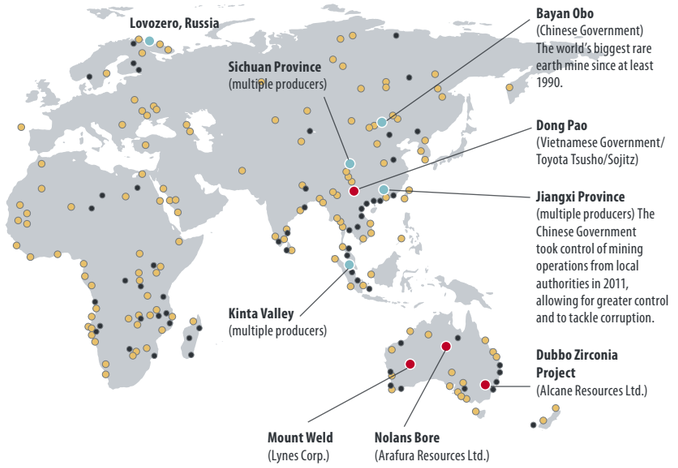
Rare earth elements

Reserves, production and consumption

China produces almost 85% of rare earth elements and consumes around 60% of the global supply. Suppliers outside of China are developing capacity.







Map key

- Identified rare earth deposit
- Site that produces or has produced at least some rare earths
- Current major producer
- Could be a major producer within five years

Source: Analysis by DCDC based on information from the US Geological Survey and other open source reporting. Original design concept New York Times.

* Member states: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan and Uzbekistan; and participating states Turkmenistan and Ukraine.

The Environment

A growing population will demand more food and water, increasing the strain on the environment out to 2045. As centres of population cluster in vulnerable areas such as coastal regions, the consequences of adverse weather are highly likely to be felt more keenly. By 2045, climate change is likely to have more noticeable effects. Without mitigation, rising sea levels will increase the risk of coastal flooding, particularly in regions affected by tropical cyclones. Droughts and heatwaves are also likely to increase in intensity, duration and frequency. Some of these events could precipitate natural disasters which, because of the interdependencies enabled by globalisation, may have consequences far beyond the site where the disaster occurs.

People and the environment

Human activities are likely to continue to have an impact on the environment. The processes of urbanisation, deforestation, industrialisation, agriculture and fishing have damaged the natural environment. By some estimates, pollution and soil erosion have led to as much as 25% of available land being degraded.[1] Similarly, over-fishing and pollution have reduced the amount of food that can be harvested from the oceans. However, more sustainable farming and fishing methods and better industrial and urban practices could mitigate these adverse effects.

Climate change

Inertia in the climate system means that historic greenhouse gas emissions will almost certainly affect the climate for the next few decades, regardless of any mitigating action taken. By 2045, average global temperatures are likely to have increased by approximately 1.4°C above levels recorded at the end of the 20th century.[2] Without concerted action,[3] it is unlikely that it will be possible to prevent global average temperatures rising more than 2°C above pre-industrial levels.[4] Although there may appear to have been no significant increase in temperatures over the last 10-15 years, periods of slow-down and speed-up in global temperature trends have occurred before, and are likely to occur again. Energy which would usually manifest as a rise in surface temperature is also being absorbed elsewhere in the Earth system, primarily in the oceans. Observations of ocean heat content and of sea-level rise re-enforce this conclusion.[5]

1 Re|Source Conference (2012), 'The Challenge of Feeding 9–10 billion People Equitably and Sustainably', available at http://www.reversethefuture.org/media/medialibrary/2012/07/Professor_Charles_Godfray_-_ReSource_2012_Food_Briefing.pdf

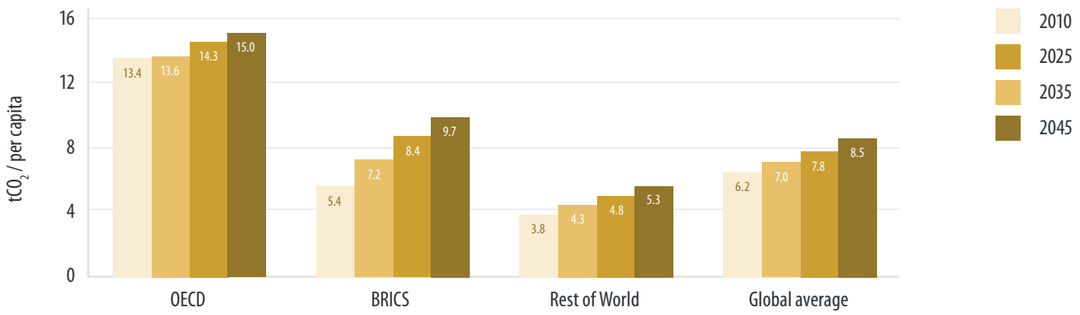
2 Kent, C. and Lewis, K., Met Office Hadley Centre (2014), 'Climate Change for Global Strategic Trends out to 2045'. It is worth noting that future temperature predictions are projections based on computer modelling, and hence are subject to the inherent uncertainties involved in such modelling, as well as to the uncertainties associated with any kind of prediction.

3 Rogelj, J. *et al.* (2012), 'Global Warming Under Old and New Scenarios Using IPCC Climate Sensitivity Range Estimates'

4 Intergovernmental Panel on Climate Change (2014), 'Fifth Assessment Report'. Hereafter referred to as 'IPCC AR5 (2014)'. AR5 data is used throughout GST 5 where available; AR4 data is used when AR5 data has not yet been published or interpreted.

5 Kent, C. and Lewis, K, *op. cit.*

Amount of CO_2 emitted per capita



Source: Based on Organisation for Economic Co-operation and Development (OECD) Environmental Outlook to 2050: Output from IMAGE/ENV-Linkages

"Without mitigating action, on a per capita basis, most developed countries' emissions are likely to remain higher than those of most developing countries."

Without meaningful effort to secure global consensus on the scale of the problem and how it should be tackled, it will almost certainly be challenging to limit global temperature increases. By the end of the century, the Earth's climate is likely to be substantially warmer and different from today's. A large body of scientific evidence indicates that climate change is mostly being driven by human-caused greenhouse gas emissions,[6,7] particularly carbon dioxide (CO_2) from generating power. While the proportion of CO_2 emitted by developing countries (particularly India and China) is likely to increase significantly out to 2045 without mitigating action, on a per capita basis, most developed countries' emissions are likely to remain higher than those of most developing countries.

Abrupt events (or tipping points) such as the failure of the Indian monsoon, changes in large-scale ocean circulation (for example a weakening of the Gulf-stream), substantial melting of the Greenland ice sheet and the release of large quantities of methane from the ocean floor are possible. All could cause major global disruption, although it is not possible to quantify the likelihood of these events occurring by 2045. Heatwaves and extremely hot days are likely to become more frequent and intense, as are droughts, while instances of extreme cold are likely to reduce. It is also probable that instances of intense rainfall will increase and that extra-tropical storms move pole-ward.[8] Historically,

6 'Greenhouse Gas' refers to CO_2 (approximately 0.04% of the atmosphere), methane (CH4), nitrous oxide (N2O) and various fluorinated gases as well as water vapour (gaseous H2O).

7 The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) found good agreement between climate models for the global temperature to increase throughout the 21st century, primarily driven by changes in Greenhouse Gas (GHG) concentrations. This assessment holds for current report. See IPCC AR5 (2014).

8 Knutson, T. R. *et al.* (2010), 'Tropical Cyclones and Climate Change'

Shock:

Catastrophic climate change

If advances in energy technology are insufficient to ensure the required amounts of electricity for economic growth, countries could burn hydrocarbons at ever-higher rates. This may increase greenhouse gas levels, causing global temperature rise. In turn, this could lead to long heat waves in normally temperate latitudes. Sustained drought could contribute to repeated harvest failures, as arable crops would be unable to cope with the high temperatures. Severe food shortages could lead to sudden mass migration of populations across national borders, triggering widespread social unrest.

the flooding in Pakistan in 2010 displaced an estimated 20 million people, and damaged 1.6 million homes. Similarly, some experts believe that a 2.5cm rise in sea levels would displace 50 million people in the coastal regions of India.[9] The economic impact of extreme events is uncertain, but losses per event from 1980-2010 ranged from a few billion US dollars (USD) to over US$ 250 billion in 2005 following Hurricane Katrina.[10] It seems likely that developing countries will feel the economic impact of climate change particularly sharply, as they are unlikely to have the resources to mitigate its effects as successfully as more developed countries.

The Arctic is likely to see significant change with the melting of sea-ice opening up new routes across the Arctic Ocean during the summer months. Reduced summer sea-ice may present opportunities as new trade routes and areas rich in natural resources open up for exploitation. Thawing permafrost could make transportation to and from Arctic oil and gas facilities problematic as ice roads turn to marsh, particularly in Siberia. The softening of the ground is likely to make new areas suitable for agriculture.

Rising sea levels

Global sea-levels are likely to rise by between 0.32–0.38 metres by 2050, although larger increases cannot be ruled out.[11] The effects of sea level rise will not be uniform across the globe and there will be regional variations which affect the vulnerability of certain coastal regions. Currently, between 270 and 310 million people are believed to be at risk of coastal flooding.[12] By 2045, a growing number of low-lying islands could be at risk of near total submersion – displacing entire communities. Without measures to mitigate and adapt to the effects of sea-level rises, by 2045 there could be between 80 and 130 million more people at risk from flooding, three-quarters of them in Asia.[13]

Desertification

Arid and semi-arid areas cover about 40% of Earth's land surface and are home to more than two billion people.[14] These areas are

9 DCDC conversations with the Institute for Defence Studies and Analyses (IDSA), India, February 2014.

10 Estimated property damage totalled US$ 108 billion, with economic impact assessments estimating losses of US$ 150 billion. See Blake, E. S. *et al.* (2011), 'The Deadliest, Costliest, and Most Intense US Tropical Cyclones from 1851 to 2010 (And Other Frequently Requested Hurricane Facts)'; Burton, M. L. and Hicks, M. J. (2005), 'Hurricane Katrina: Preliminary Estimates of Commercial and Public Sector Damages'

11 Jevrejeva, S. *et al.* (2012), 'Sea Level Projections to AD2500 with a New Generation of Climate Change Scenarios'

12 Hinkel, J. *et al.* (2014), 'Coastal Flood Damage and Adaptation Costs Under 21st Century Sea-Level Rise'

13 Jongman, B. et al. (2012), 'Global Exposure to River and Coastal Flooding: Long Term Trends and Changes'; Met Office (2013), 'Sea-Level Rise' available at http://www.metoffice.gov.uk/climate-change/guide/impacts/high-end/sea-level

14 UN FAO (2008), 'Water and Cereals in Drylands'; Warner, T. (2004), 'Desert Meteorology'

Scenario:

City concentration and sea level rise

If our use of coal-fuelled power stations increases out to 2045 (perhaps as developing countries build their economies), alongside a possible demand from the growing consumer class for larger, higher-status petrol-driven cars, it is conceivable that global warming could significantly increase, perhaps by as much as 3°C. With such a rise in temperature, significant melting of Arctic ice-sheets could occur, releasing vast amounts of methane and raising temperatures (and hence sea-levels) even higher.

Current trends indicate that a number of mega-cities will be in littoral areas. If this coincides with climate-change-induced sea level rise and extreme weather events, the consequences could be disastrous – particularly in those rapidly expanding cities in developing countries where governance is weak.

"Between 270 and 310 million people are believed to be at risk of coastal flooding."

expanding, with one study suggesting an estimated 135 million people will be at risk of being displaced by desertification over the coming decades, due to water shortages and reduced agricultural output.[15] In sub-Saharan Africa alone, some 60 million people are expected to move from 'desertified' areas to northern Africa and Europe by 2020, and this figure is highly likely to increase out to 2045.

"Around 20-30% of plant and animal species could be at high risk of extinction due to climate change."

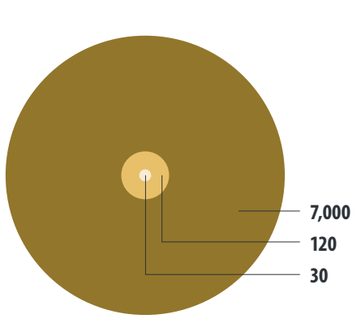
Water

Future water stress is likely to be mainly driven by socio-economic factors.[16] The frequency, intensity and duration of droughts in many parts of the world are likely to increase. Climate change is likely to contribute to longer-term changes in water availability, particularly in areas dependant on glacier melt-water. The continued melting of glaciers could increase freshwater availability out to 2045, but may bring with it an increased risk of localised flooding. In the longer term, as glaciers melt, the inter-annual reliability of the supply of water in glacial rivers will be affected. Changing rainfall patterns may mean declining water availability for some, and an excess for others.

15 Global Humanitarian Forum (2009), 'Human Impact Report - Climate Change', available at http://www.ghf-ge.org/human-impact-report.pdf

16 Kent, C. and Lewis, K., *op. cit.*

Concentrated reliance on 30 crop species



*Source: FAO http://www.fao.org/biodiversity/components/plants/en/

†Source: Shiva, V., Buiatti, M., Ceccarelli, S., Dolder, F., Esquinas, J. T., Mammuccini, M. G., Magarinos-Rey, B. & Pucci, G. (2013) 'The Law of the Seed', Navdanya International, p.9. (http://www.navdanya.org/attachments/lawofseed.pdf)

Marine life

Marine ecosystems are expected to undergo substantial change by 2045.[17] For example, numerous studies suggest that the increasing acidity of the ocean (due to greater absorption of carbon dioxide) will have harmful consequences for calcifying organisms such as coral reefs and many species of shellfish.[18] Around inland and coastal areas, changing patterns of freshwater runoff, droughts, floods, increasing temperatures and rising sea levels could all have a significant negative effect on fisheries and aquaculture.[19] Inland fisheries are particularly vulnerable to low water levels, changes in spawning grounds, water extraction and modifications to river courses (such as the construction of dams). Freshwater runoff could reduce the salinity of seawater, adversely affecting fishing grounds and coral reefs. Aquaculture depends heavily on adequate water exchange and is vulnerable to temperature extremes and storm damage, particularly in coastal areas.

Biodiversity

The impact of pollution, habitat destruction and climate change will almost certainly have a profound effect on wildlife. Some species are likely to adapt to the changes in their environment but many may not be able to. More species will almost inevitably become extinct, with the OECD's projections indicating that terrestrial biodiversity could decrease by up to 10% by 2050.[20] The UN assesses that biodiversity loss has been more rapid in the last 50 years than in any other period in human history,[21] a trend that some commentators suggest shows no sign of slowing.[22] Around 20-30% of plant and animal

17 Fischlin, A. *et al. op. cit.*

18 IPCC AR4, *op. cit.*; Bellard, C. *et al.*, *op. cit.*; Wittmann, A. C. and Pörtner, H. O. (2013), 'Sensitivities of Extant Animal Taxa to Ocean Acidification'

19 FAO (2009), 'Report of the Expert Workshop on Climate Change Implications for Fisheries and Aquaculture', available at http://www.fao.org/docrep/011/i0203e/i0203e00.htm

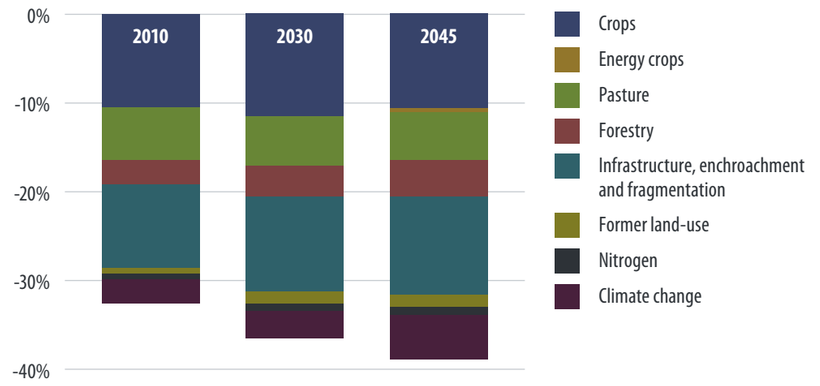
20 OECD (2012), 'Environmental Outlook to 2050'

21 UN Millennium Ecosystem Assessment Board (2005), 'Ecosystems and Human Well-Being', available at http://www.unep.org/maweb/documents/document.354.aspx.pdf

22 Karkkainen, B. (1997), 'Biodiversity and Land'

Pressures driving global biodiversity loss

Projected **Mean Species Abundance*** loss as the result of different human induced pressures, with a large role for agricultural land use, encroachment and climate change.



Source: OECD Environmental Outlook to 2050

* This is a way of measuring the impact of human behaviour on ecosystems. It compares the current number and variety of species in a particular area with historic data, to assess the major causes of biodiversity loss.

species could be at high risk of extinction due to climate change.[23] Reduction in biodiversity decreases the natural environment's resilience when adapting to change, since genetic diversity is the raw material for evolution. A reduction in biodiversity could also lead to the loss of organisms that keep pest and disease species in check. There may also be significant economic consequences to biodiversity loss, with some suggestions that the annual cost to the global economy is between US$ 2bn and US$ 5bn.[24] Reduction in biodiversity may also place food supplies at risk. At present, four crops (rice, wheat, maize and potato) provide more than 60% of global food energy.[25] Relying so heavily on such a small number of crops means that, if growing conditions change (due to drought, increased temperatures or flooding, for example), we may not have sufficient genetic variety to be able to breed crops to cope with these environmental stresses.

23 Fischlin, A. *et al.* (2007),'Ecosystems, Their Properties, Goods, and Services'; Bellard, C. *et al.* (2012), 'Impacts of Climate Change on the Future of Biodiversity'

24 OECD, *op. cit.*

25 UN FAO (2014), 'Biodiversity: Plants'

Agriculture

The impact of climate change on agriculture is complex and region-dependent. Adverse impacts (for example, heatwaves, droughts, storms and flooding) are expected across tropical regions[26] and much of the Mediterranean basin.[27] Higher latitudes are likely to experience a range of both positive and negative impacts (such as changes in water availability, heat stress , increased growing seasons and decreases in the occurrence of frost damage).[28] Until about 2050, modest warming is expected to improve growing conditions for a range of crops in the mid- and high-latitudes.[29] Increased atmospheric carbon dioxide could also increase the growth rates of many plant

26 IPCC AR4, *op. cit.*

27 Ferrise R. *et al.* (2013), 'Climate Change Impacts on Typical Mediterranean Crops and Evaluation of Adaptation Strategies to Cope With'

28 Gornall, J. *et al.* (2010), 'Implications of Climate Change for Agricultural Productivity in the Early Twenty-First Century'

29 Fischlin, A. *et al. op. cit.*

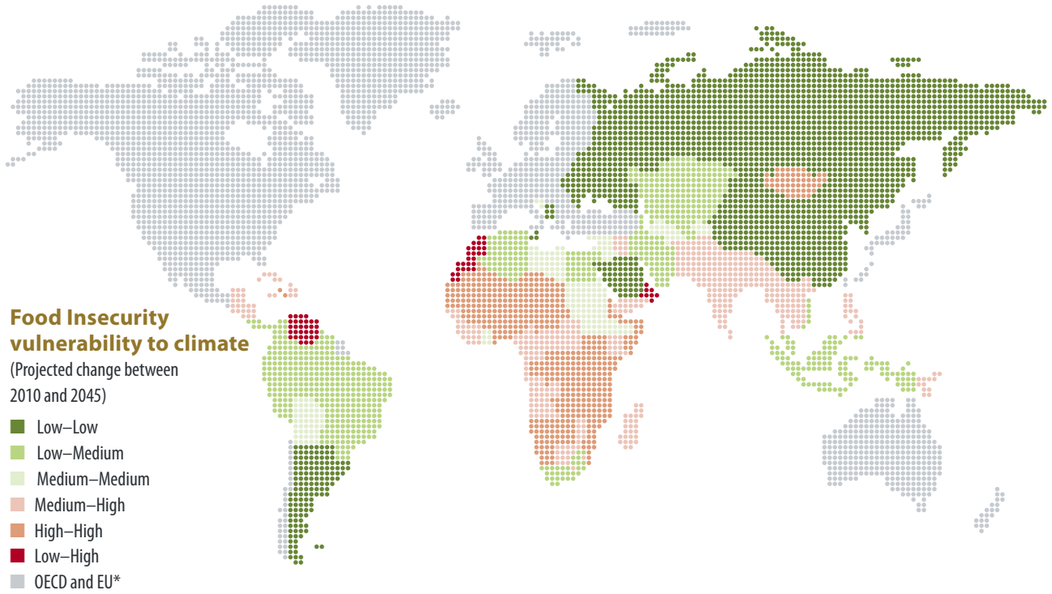
species.[30] However, the indirect impacts of climate change – wildfires, land degradation, pests and diseases, extreme rainfall and sea-level rise – could have significant effects. For example, it is currently estimated that each year 10-16% of the total global harvest is lost to plant diseases,[31] and climate change could increase this figure by 2045. Nevertheless, a great deal of the world's agricultural potential is unused or under-used. If this 'yield gap' could be closed, perhaps by technological improvements, GM crops and improved methods of agriculture and farming, the trend towards a decrease in food production could be slowed or reversed. Even using current technology, the potential exists to increase production by up to 40%.[32]

About 60% of the workforce in developing countries (around 1.5 billion people) is employed in agriculture, livestock, fisheries and tourism. While the proportion of people working in these areas is expected to reduce (not least due to increased urbanisation), many are still likely to depend on the health of the natural environment for their livelihoods and may therefore be particularly vulnerable to the effects of climate change and environmental degradation. Degraded and threatened environments are likely to lead to affected communities migrating – with potentially destabilising consequences.

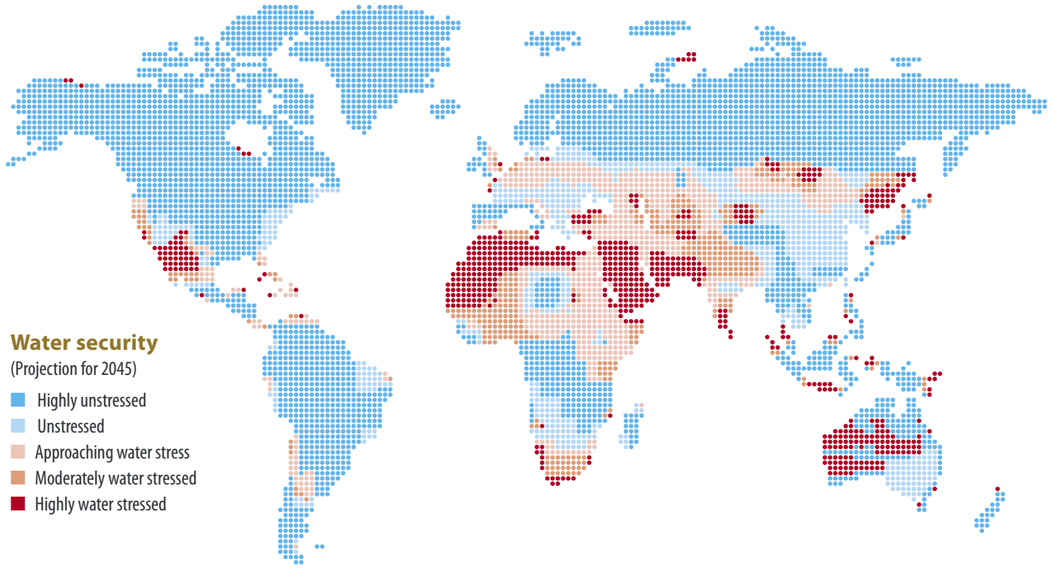
30 Notaro, M. *et al.* (2007), 'Global Vegetation and Climate Change due to Future Increases in CO_2 as Projected by a Fully Coupled Model with Dynamic Vegetation'

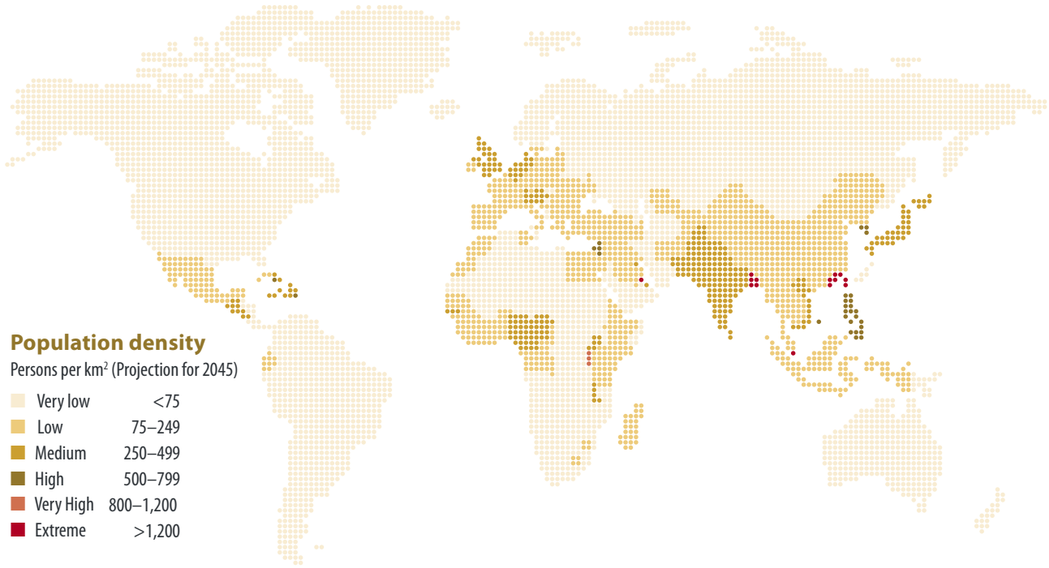
31 Chakraborty, S. and Newton, A. C. (2011), 'Climate Change, Plant Diseases and Food Security: An Overview'

32 Department for International Development (2014), unpublished comments at the Horizon Scanning Office for Government (GOSH).



*OECD and EU countries are not considered at risk due to their economic means and access to global food markets





Sources:

Climate Security Team, Met Office Hadley Centre (2014), 'Climate Change and Food Security: Measuring Climate Impact Through the Hunger and Climate Vulnerability Index'

Wiltshire, A. J., Kay, G., Gornall, J. L., and Betts, R. A. (2013), 'The Impact of Climate, CO_2 and Population on Regional Food and Water Resources in the 2050s'

Wiltshire, A., Gornall, J., Booth, B., Dennis, E., *et al.* (2013), 'The Importance of Population, Climate Change and CO_2 Plant Physiological Forcing in Determining Future Global Water Stress.'

UN World Urbanization Prospects: 2011 Revision

Sudanese mothers and their malnourished babies gather at a field hospital

Humanitarian relief

The financial requirements for humanitarian assistance are projected to increase by up to 1,600% over the next 20 years, in large part due to the effects of climate change.[33] By 2045, this figure is likely to be substantially higher. Funds available for disaster preparedness and relief are widely assessed to be inadequate. As the incidence and impact of natural disasters increase, this situation is likely to worsen. Governments, particularly those in the regions most affected, are likely to become increasingly focussed on: preventing, preparing for (and dealing with) the impact of environmental and climate related disasters at home; and with providing humanitarian assistance and disaster relief abroad. Some governments are likely to require their armed forces to take on an increased role in disaster relief.

Intervention and prevention

Reducing greenhouse gas emissions is likely to be the most important means by which climate change is managed – although out to 2045 it appears likely that the drivers of greenhouse gases will continue to increase. Inertia in the climate system means that warming would continue even if emissions were cut to zero tomorrow. Catching greenhouse gases before they are released into the atmosphere through techniques such as carbon capture and storage could play a vital role in reducing climate change – particularly while fossil fuels remain a major energy source.[34] Although at an early stage of development, and with questions remaining about whether they could operate on a large scale, more advanced carbon capture technologies have the potential to convert carbon into useful products such as plastics.[35] At a local level, constructing flood defences, altering agricultural practices in light of changing weather patterns and implementing water conservation measures are likely to be the primary means of adapting to the effects of climate change.

33 Webster, M. *et al.* (2008), 'The Humanitarian Costs of Climate Change'

34 Bosetti, V. *et al.* (2009), 'Optimal Energy Investment and R&D Strategies to Stabilize Atmospheric Greenhouse Gas Concentrations'

35 IEA (2009), 'Technology Road Map, Carbon Capture and Storage', available at http://www.iea.org/publications/freepublications/publication/TechnologyRoadmapCarbonCaptureandStorage.pdf

Theoretically plausible geoengineering methods (intentional, large-scale activities intended to counteract aspects of climate change) have been proposed for a number of years.[36] Detailed studies on the environmental implications of different geoengineering activities have recently begun to appear, but large-scale testing and implementation of such methods has not occurred – in some cases due to public opposition.[37] One theoretical 'solar radiation management' technique would aim to disperse sulphates into the upper atmosphere, reflecting the sun's rays back out to space, producing a cooling effect. However, as with most geoengineering techniques, there are questions about how to maintain the intervention, and minimise the potentially harmful side-effects. For example, it is not known what the long-term effects of dispersing large quantities of sulphates into the atmosphere would be. Over-reliance on particular geoengineering technology to mitigate the effects of climate change could also render users vulnerable to catastrophic effects if equipment failed or was sabotaged. It is not clear therefore what, if any, role geoengineering will play by 2045 in countering the effects of climate change, and the extent to which it could heighten international tensions.

36 The Royal Society (2009), 'Geoengineering the Climate: Science, Governance and Uncertainty'; Political and governance issues discussed by Bodansky, D. (2012), 'The Who, What, and Wherefore of Geoengineering Governance'

37 Lenton, T. M. and Vaughan, N. E. (2009), 'The Radiative Forcing Potential of Different Climate Geoengineering Options'; Kravitz, B. *et al.* (2011), 'The Geoengineering Model Intercomparison Project (GeoMIP)'; Kravitz, B. *et al.* (2013), 'Climate Model Response from the Geoengineering Model Intercomparison Project (GeoMIP)'

"Advanced carbon capture technologies have the potential to convert carbon into useful products such as plastics."

Defence and security implications

- Extreme weather events, such as flooding and droughts, are likely to increase in both frequency and intensity in a number of regions. Extreme events will almost certainly continue to cause widespread damage and loss of life, although our warning mechanisms, defences and ability to respond may also improve in the same timeframe.
- Reductions in the extent of summer Arctic sea-ice could open up new shipping routes during the summer months and boost economic growth in the region – increasing its strategic significance for many countries.
- Degraded and threatened environments are likely to lead to affected communities migrating – with potentially destabilising consequences.
- Armed and security forces, both at home and abroad, are likely to be more frequently tasked with providing humanitarian assistance and disaster relief, perhaps supporting indigenous responders.
- Without mitigation measures such as carbon capture and storage, continued reliance on coal and hydrocarbons for the majority of energy demand may exacerbate climate change and its knock-on effects.

Health

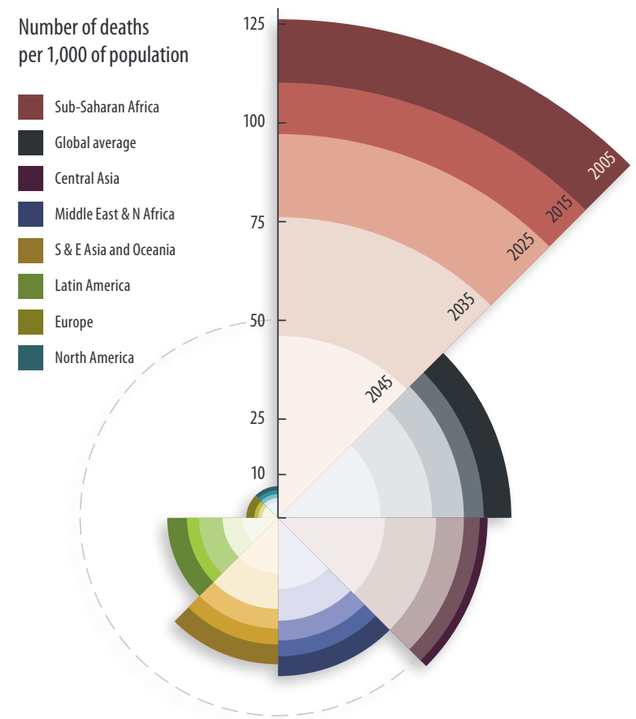
Developments in technology are likely to lead to significant improvements in medicine and health, such as the potential for developing cures for some cancers by 2045. Advances in diagnostic techniques, the development of artificial organs and mind-controlled prosthetic limbs mean that we are highly likely to live for longer and have more productive lives. But new challenges to good health will almost certainly emerge. Rising physical inactivity and unhealthy diets are likely to contribute to an obesity epidemic and a rise in non-communicable diseases. Antibiotic-resistant pathogens could be widespread by 2045, making post-operative infections potentially lethal.

Impediments to health

Globally, significant progress has been made in reducing levels of child mortality. Between 1990 and 2012, the number of under-fives dying each year fell from 12 million to 6.3 million, and further decreases look likely. However, more than one third of the global population (approximately 2.5 billion people) currently lack access to adequate sanitation, and despite efforts to reduce it, due to the probable increase in the number of people living in slums, this figure is likely to grow out to 2045. Perhaps the most serious development in global health is the increase in the prevalence of non-communicable diseases (such as cardiovascular diseases, diabetes, cancers) which – following the success of treatments for communicable diseases – have become the leading global causes of death, particularly in developing countries.[1] Of the 57 million deaths in 2008, 63% were due to non-communicable diseases. They are the most frequent causes of death in most countries, except those in Africa. Even here, the incidence of non-

1 WHO (2011), 'Global Status Report on Noncommunicable Diseases 2010', available at http://www.who.int/entity/nmh/publications/ncd_report_summary_en.pdf

Falling under five mortality



Source: UN (2012), 'World Population Prospects: The 2012 Revision'

"Outdoor urban air pollution currently causes about 1.2 million deaths every year, and this number is likely to increase out to 2045."

communicable diseases is rising rapidly.[2] This global rise is mainly attributable to population growth; ageing; and economic transition and the resulting changes in behavioural, occupational and environmental risk factors. Most non-communicable diseases are strongly associated, and causally linked, with four particular behaviours: tobacco use; physical inactivity; unhealthy diet; and the harmful use of alcohol.[3]

Antimicrobial resistance among bacteria, viruses and fungi is increasing. If current trends continue, antimicrobial resistant pathogens could be prevalent by 2045 or sooner. This could make surgery and medical procedures such as chemotherapy (which suppresses the body's immune systems) much more hazardous. Already, 25,000 people a year die in Europe due to antimicrobial resistance. The consequences of infected wounds on military operations would also become more serious if we returned to a 'pre-antibiotic' era. Moreover, research and development for new antimicrobials is very limited – no new class of antibiotics has been developed since 1987. However, alternatives to antibiotics are being examined, including using vaccines, metals[4] and viral agents.[5]

Emerging infections and the risk of pandemics

Up to 70% of recent emerging infections have originated in animals and this will almost certainly continue to be the case out to 2045. The time and location of new infections (or re-emergence of already known infections) cannot be accurately predicted, but places where animals and humans interact are likely to be particularly problematic. The likelihood of disease outbreak could, however, be mitigated by alertness to changing trends in infectious diseases (in both humans and animals), joined-up surveillance strategies and sharing of information across disciplines and borders.

Climate change

Climate change is already affecting health, contributing to a decline in clean air, safe drinking water, sufficient food and secure shelter across the globe. Increased frequency and intensity of extreme weather events are likely to affect physical health (such as heat-related illness) as well as mental health problems,[6] such as increased stress due to the impact of flooding.[7] Higher temperatures are also likely to raise the levels of ozone and other pollutants in the air that exacerbate cardiovascular and respiratory disease. Outdoor urban air pollution currently causes about 1.2 million deaths every year,[8] and this number is likely to increase out to 2045. Climatic conditions strongly affect water-borne diseases and diseases transmitted through insects,[9] snails or other cold-blooded animals. Lengthening transmission seasons of important vector-borne diseases, such as dengue fever, could also alter their geographic range.[10] The loss or contamination of fresh water is almost certain to lead to disease and crop destruction – resulting in food shortages, poor nutrition and malnutrition. Longer-term changes in weather patterns may lead to significant decreases in fertility of farmland and water availability in some areas.[11]

2 *Ibid.*

3 WHO (2011), *op. cit.*

4 Lemire, J. A. *et al.* (2013), 'Antimicrobial Activity of Metals: Mechanisms, Molecular Targets and Applications', available at http://www.nature.com/nrmicro/journal/v11/n6/abs/nrmicro3028.html

5 Mathur, M. D. *et al.* (2003), 'Bacteriophage Therapy: an Alternative to Conventional Antibiotics', available at http://www.ncbi.nlm.nih.gov/pubmed/15266928; Borrell, B. (2012), 'Could Bacteria-Fighting Viruses Replace Overused Antibiotics?', available at http://www.scientificamerican.com/article.cfm?id=could-bacteria-fighting-viruses-replace-antibiotics

6 WHO (2013), 'Climate Change and Health: Factsheet No. 266', available at http://www.who.int/mediacentre/factsheets/fs266/en/

7 Health Protection Agency (2011), 'The Effects of Flooding on Mental Health', available at http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317131767423

8 WHO (2013), *op. cit.*

9 WHO (2014), 'Climate Change and Vectorborne Diseases', available at http://www.wpro.who.int/mvp/climate_change/en/

10 Costello *et al.* (2009), 'Lancet and University College London Institute for Global Health Commission'

11 Met Office (2012), 'Climate Impacts on Food Security and Nutrition', available at http://www.metoffice.gov.uk/climate-guide/climate-change/impacts/food

170 million children globally are overweight or obese

Obesity

Were obesity to be considered a disease, there would arguably already be a global obesity pandemic.[12] By 2008, an estimated 1.5 billion adults globally were overweight and 500 million adults were obese. An estimated 170 million children globally were also classified as overweight or obese. This includes more than 25% of all children in some countries – more than double the proportions from the start of the global rise in obesity in the 1970s. Unlike other major causes of preventable death and disability, such as tobacco use, injuries and infectious diseases, there are no examples of populations in which rising obesity has been reversed by public health measures. The increases in obesity in adults are widely projected to continue to rise in the next 10 to 20 years. However, some reports are emerging from countries such as Sweden, Switzerland, France and Australia which indicate that overweight and obesity prevalence in some childhood age-groups may be flattening or even decreasing, although overall occurrence is still high. Very few countries have adequate monitoring systems in place to track different populations.

Ageing

In 1950, there were 200 million people aged over 60 across the world – by 2050, the number is likely to be around two billion,[13] nearly a quarter of the global population. Over the past century, advances in medicine have contributed to people living longer and healthier lives. However, as we live longer, different types of diseases, such as dementia, are likely to become more prevalent. Current estimates indicate 35.6 million people worldwide are living with dementia. This is likely to double by 2030 and more than triple by 2050 if no treatment is found. Dementia is a costly condition:

12 Swinburn, B. A. *et al.* (2011), 'The Global Obesity Pandemic: Shaped by Global Drivers and Local Environments'

13 Aging Societies Working Group 2012 (2012), 'Creating Sustainable Health and Care Systems in Aging Societies', available at http://www.ilcuk.org.uk/images/uploads/publication-pdfs/GHPS_Ageing_Societies_Report.pdf

socially, economically, and on the quality of life of those afflicted by it. Nearly 60% of the burden of dementia is concentrated in low- and middle-income countries and this is likely to increase in coming years. More modern medical advances have also turned many life-threatening conditions such as some cancers and heart disease into long-term conditions, as more people survive acute episodes of illness and live for many years with their conditions. This helps to explain why the extra years of life that people have gained are not always healthy or disability free.

Mental health

The global cost of mental health conditions in 2010 was estimated at US$ 2.5 trillion. This is likely to more than double to US$ 6.0 trillion by 2030.[14] Of these costs, 65% are incurred by developed countries and this is not expected to change over the next 20 years. By disease, mental illness accounted for the largest share of the global economic burden in 2010 and is likely to in 2030, just slightly more than cardiovascular diseases (followed by cancer, chronic respiratory disease and diabetes). Mental health conditions are the leading cause of healthy life years lost worldwide and account for 37% of the healthy life years lost from non-communicable diseases.[15]

"Mental health conditions are the leading cause of healthy life years lost worldwide."

Prevention, monitoring and diagnosis

Improved computing power, data collection and processing are likely to make medical diagnosis quicker, cheaper and more accurate. Through implementing global standards, medical information such as patient records could be shared by clinicians in different countries. With a globalised medical information network interlinked with millions of sensors, advanced analytical systems could identify, track and predict the spread of disease, providing information so that preventative measures can be quickly put in place. Similarly, portable medical devices that can be linked to medical networks may mean that remotely operated (or automated) medical systems will allow larger numbers of patients to be treated and cared for in their own homes.

Alternative outcome:

Drop in non-communicable diseases

Current trends suggest that there is likely to be a rise in deaths from non-communicable diseases out to 2045. However, this could be reduced or reversed if: large-scale lifestyle and behavioural changes are made; access to primary healthcare is improved; and research into preventative medicine or cures proves fruitful.

Drug and treatment delivery

In 2001, the first camera pill was approved by the US Federal Drug Administration for diagnostic applications. Seven years later, a pill capable of being electronically programmed to control medicine delivery according to a pre-defined drug release profile was ready for serial manufacturing, and being used as a research and development tool.[16] Current advances have produced a pill which can monitor the patient, communicate with external diagnostic systems and respond to instruction for the targeted delivery of drugs within the digestive tract. The next evolution will probably see further integration of monitoring and drug delivery, with automated diagnostic and response systems. As technology advances, the size of devices is likely to be reduced while retaining the same capability. It seems probable, therefore, that there will be future medical devices small enough to travel in the bloodstream.

Personalised medicine

The field of pharmaco-genomics (the study of how an individual's genetic inheritance affects the body's response to medicines) is in its infancy, but holds the promise that medicines might be tailor-made to a person's genetic makeup – making medicines more effective and safe.[17] New approaches are being developed, which should make precise medicine formulations, treatment duration and dosing for individuals possible.[18] The ability to determine the genetic basis for certain toxic side effects would allow medicines to be prescribed to those who are not genetically at risk of such side effects, thereby paving the way for potentially lifesaving medicines that may otherwise be taken off the market.[19] Whole genome sequencing is also likely to increase the diagnosis rate for rare diseases and stimulate new treatment development.

Regenerative medicine

Active bio-materials have the potential to provide an alternative to surgery and transplants by allowing in-situ repair and regeneration of damaged tissue.[20] These materials could deliver drugs to particular sites or activate specific genes that stimulate live tissue to regenerate.[21] Using stem cells (either separately or combined with active biomaterials or DNA engineering to correct genetic defects)[22] may lead to a new kind of cell-based medicine that could be applied to every system in the human body, offering an alternative approach to treatment by medicines. Possibilities include: growing entire organs to replace damaged ones; providing an endless supply of red blood cells for transfusion; and treating severe burns with bio-materials.[23] Neural stem cells may also be used to treat spinal cord injury and replace damaged neurons in the brain.[24] Novel medical and surgical interventions such as these will almost certainly improve casualties' survival and recovery rates.

Prosthetics

Artificial limbs that connect to the wearer's nervous system are already being developed. Neural receptors that are able to control mechanical limbs are in use today, significantly improving the quality of life of those who possess them.[25] Developments in this area are likely to see refinement of control to provide

Shock:

Rapid medical advancements

A game-changing medical breakthrough, similar in impact to the discovery and mass-production of antibiotics, could significantly extend the human lifespan and dramatically reduce the incidence of non-communicable diseases such as cancers. Initially, this breakthrough would probably only be available to the very rich, exacerbating social tensions. As the treatment became accessible to everyone, there would be a significant impact on populations, as life span dramatically increased. Without mitigating action, there could be a subsequent unsustainable increase in demand for food, water and housing.

14 World Economic Forum (2011), 'The Global Burden of NCDs', available at http://www3.weforum.org/docs/WEF_Harvard_HE_GlobalEconomicBurden NonCommunicableDiseases_2011.pdf

15 *Ibid*.

16 Phys.org (2008), 'Philips' Intelligent Pill Targets Drug Development and Treatment for Digestive Tract Diseases', available at http://phys.org/news145640874.html

17 National Institute of General Medical Sciences (2014), 'Frequently Asked Questions about Pharmacogenomics', available at http://www.nigms.nih.gov/Research/SpecificAreas/PGRN/Background/Pages/pgrn_faq.aspx

18 Government Office for Science (2011), 'Customisation of Drugs through Biotechnology', available at http://www.sigmascan.org/Live/Issue/ViewIssue/474/5/customisation-of-drugs-through-biotechnology/

19 National Institute of General Medical Sciences, *op. cit.*

20 Government Office for Science (2012), 'Active Biomaterials for Regenerative Medicine', available at http://www.sigmascan.org/Live/Issue/ViewIssue/478/5/active-biomaterials-for-regenerative-medicine

21 *Ibid*.

22 Young, S. (2014), 'Genome Surgery' in MIT Technology Review, available at http://www.technologyreview.com/review/524451/genome-surgery/

23 Government Office for Science (2009), 'Stem Cell Research and Hope for Cell-based Medicine', available at http://www.sigmascan.org/Test/Issue/ViewIssue/473/4/stem-cell-research-and-hopes-for-cell-based-medicine/

24 Panchision, D. (2012), 'Repairing the Nervous System with Stem Cells', available at http://stemcells.nih.gov/info/Regenerative_Medicine/pages/2006chapter3.aspx

25 See, for example, the artificial hand developed by Touch Bionics http://www.touchbionics.com/products/active-prostheses/i-limb-ultra/

Some may elect to use genetic modification as a route to securing advantage

unconscious response, greater dexterity and sensory feedback, as well as providing new ways to connect the able-bodied to machines and computers.[26] By 2045, there is a real prospect that artificial devices will provide a superior level of performance than can be achieved naturally – for example, hearing-aids that can detect sounds beyond the range of the human ear.

Fertility and reproduction

The recent development of a device in which a mouse embryo was successfully implanted and able to grow for a short period of time in an artificially created environment, opens the possibility of allowing a human embryo to develop outside the body.[27] Advances in similar technology could provide a means for childless couples to have children and give greater flexibility when choosing when to have children. The ability to transfer a developing foetus to an artificial environment could enable surgical procedures to be performed that would otherwise have to follow childbirth.

The extent to which human attributes could (or should) be selected through manipulating their embryonic genetic make-up is a highly controversial area. The first child to be born after his parents had the entire genomes of a batch of their IVF embryos screened for abnormalities was reported in July 2013 in the UK.[28] This was done with the intention of selecting the healthiest for implantation but there is evidence that pre-implantation gender selection is already widespread in some societies. 42% of US clinics which offered pre-implantation genetic diagnosis were found in 2008 to allow gender selection for non-medical reasons.[29] There is clearly also scope for selecting, or engineering, other genetically-determined characteristics. Pre-implantation genetic diagnosis and screening or genetic modification is regulated in the UK but is currently commercially available in the US for around 100 medical conditions including some cancers. Some countries (and individuals) are likely to want to use techniques like genetic modification to gain a competitive advantage, while others will probably constrain their development for ethical reasons. The extent to which it will be possible to select, or influence the development of complex characteristics, such as athletic ability or intelligence, is unclear. However, it seems probable that, in time, technology will be available that will make it possible for parents to select a range of attributes for their child – though not necessarily by 2045.

Health workers

Since 2000, the number of doctors has grown in most OECD countries, both in absolute number and on a per capita basis, with only a few exceptions (Estonia, France and Israel). However, in most countries there are twice as many specialist doctors as generalists.[30] The slow growth or reducing number of generalists raises concerns about future access to primary care. There are also concerns in many countries about shortages of nurses. The demand for nurses continues to increase, with the ageing of the 'baby-boom' generation leading to greater numbers of retired people requiring nursing. There are also growing concerns about a severe global shortage in the supply of homeworkers. Trends indicate that, without successful plans for expanding this workforce, the crisis could increase in the future. Immigrants are seen as a plausible answer to this problem, at least for developed countries. There are significant flows of care workers from low- and middle-income countries to high-income countries within Europe.

> *"The extent to which it will be possible to select, or influence the development of complex characteristics such as athletic ability or intelligence is unclear."*

26 Singh, A.K. (2012), 'Robotics as a Future and Emerging Technology'

27 University of Nottingham (2012), 'Artificial 'Womb' Unlocks Secrets of Early Embryo Development', available at http://www.nottingham.ac.uk/news/pressreleases/2012/march/artificial-womb-unlocks-secrets-of-early-embryo-development.aspx

28 Geddes, L. (2013), 'First Baby Born After Full Genetic Screening of Embryos', available at http://www.newscientist.com/article/dn23827-first-baby-born-after-full-genetic-screening-of-embryos.html

29 Baruch, S. *et al.* (2012), 'Genetic Testing of Embryos: Practices and Perspectives of US In Vitro Fertilization Clinics', available at www.ncbi.nlm.nih.gov/pubmed/17628552

30 OECD (2013), 'Health at a Glance 2013: OECD Indicators', available at http://dx.doi.org/10.1787/health_glance-2013-en

Defence and security implications

- Antimicrobial-resistant infection could significantly increase medical risk on military operations.
- Novel medical and surgical interventions will almost certainly improve casualties' survival, and recovery rates.
- Advances that allow patients to interact with their prosthetics and other aids are likely to lead to new ways to connect the able-bodied to machines and computers.
- Some countries (and individuals) are likely to use advanced medical techniques, such as genetic modification, to gain a competitive advantage. Others will probably constrain their development for ethical reasons.

Transport

New materials, manufacturing techniques and power systems, as well as advances in information technology, are likely to open up new opportunities for automated transport and generate step-changes in speed and efficiency. Driverless transport is likely to be widespread by 2045, providing greater independence for the elderly and impaired. Unmanned systems could play a key role in the mass delivery of goods. New developments in super-sonic flight could make sub-orbital space transport a commercial reality in the next 30 years.

Drivers for change

Transport has not changed fundamentally since high-speed rail travel, jet-powered flight and oceangoing container transporters were introduced half a century ago. The dominance of oil as a source of energy is argued by some to have been the primary constraining factor limiting developing alternative modes of transportation.[1] However, new materials, manufacturing techniques and power systems may provide the catalyst for more significant change.

Personal transport

More efficient engines and the possible adoption of fuel cells could make transport systems more efficient and probably cheaper.[2] Increasing automation could enable a far greater density of traffic to move at higher speeds and provide automatic routing to avoid congestion and hazards. Driverless transport is likely to be prevalent by 2045, providing bespoke transport solutions for many who currently find it difficult to access a car, such as the elderly, children, and the visually, physically, and mentally impaired. Driverless transport is likely to be safer and more reliable – driverless vehicles would not be affected by human failings such as road rage, drink-driving or falling asleep at the wheel.

Mass transport

Future mass transport solutions are likely to provide faster and more closely-integrated transport using a variety of road, rail, sea and air systems. Future improvements are framed around the concept of 'seamless transport', the idea that journeys could be taken without interruption. This would reduce waiting or travel time and there could be an ability to do other tasks while travelling.[3] To achieve this, there is likely to be closer integration and coordination across infrastructure and transport providers, as well as adopting automated systems. Unmanned systems could play a much greater role in the mass delivery of goods. For example, an urgent, high-value product (such as blood of a rare type), could be quickly delivered. While Amazon's recently proposed remotely piloted aerial delivery system may seem like

"Driverless transport is likely to be prevalent by 2045, providing bespoke transport solutions for many."

1 Rodrigue, Jean-Paul (2013), 'The Geography of Transport Systems'

2 Scott, C. (2014), 'Hydrogen Vehicles, Long Promised, Finally Hit the Road', available at http://singularityhub.com/2014/01/08/hydrogen-vehicles-long-promised-finally-hit-the-road/

3 OECD (2012), 'International Transport Forum: Summary of Findings – Consultation with International Organisations On Seamless Transport', available at http://www.internationaltransportforum.org/2013/pdf/Findings_Consultation2012.pdf

Aircraft will be able to travel at many times the speed of sound

science-fiction, the European Commission and US Federal Aviation Authority have both published remotely piloted air systems airspace integration roadmaps. We may see many more such aircraft, both large and small, in future skies, meaning that aircraft providing passenger travel may have to compete for space, particularly over urban areas. However, greater reliance on automated technologies could provide scope for terrorists and criminals to disrupt the transport system through cyber attacks.

Super-sonic flight

With the final flight of the Concorde in 2003, an era of super-sonic passenger flight ended, but developments in design and engine technology have continued. New concepts such as variable-cycle engines (an engine that is designed to operate efficiently under mixed flight conditions, such as subsonic, transonic and supersonic) and recent successes with other reaction engines, offer the potential for very high speed travel at many times the speed of sound. Striving for increased range and fuel efficiency, combination power sources are likely to see a blend of conventional hydrocarbon-fuelled and electrically-powered flight – advances which are also likely to improve stealth capabilities suited to military applications. The major global manufacturers have announced their intent to develop aircraft which deliver these objectives by around 2030. In the 15 years following, developments to further improve efficiency, capacity and speed are near certain to continue, with commercial sub-orbital flight between two destinations likely by 2045 or sooner.

Transportation of material

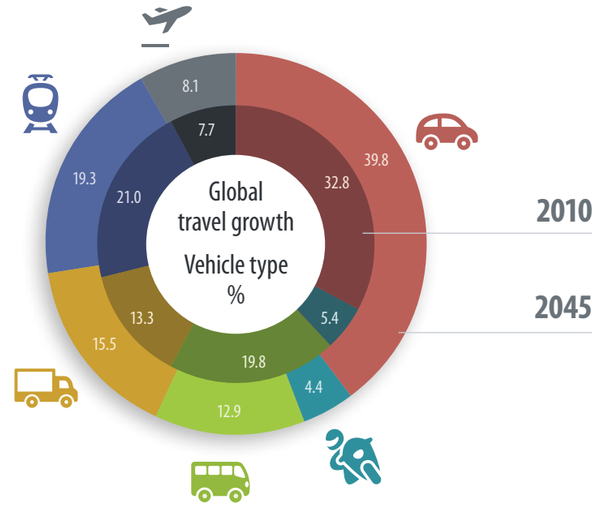
On current trends, by 2045 the tonnage of material moved by sea is likely to have doubled, as are the number of international flights. This could lead to increasingly congested shipping lanes and air corridors, although greater connectivity and computing-power may enable more efficient traffic management. However, international governance will almost certainly be required if this is to happen successfully. Increased computing power and connectivity could also increase efficiency – for example, routes could be automatically optimised to take into account traffic and weather forecasts. This could reduce the risk of loss and damage when transporting commodities such as perishable foods. Technology is also likely to improve inventory management, by automatically monitoring consumption levels. This could allow spares to be safely dispatched in sufficient time – large amounts of expensive stock would no longer have to be held in readiness for prolonged periods.

If fewer inventory items were being routinely transported, the resources needed for transportation could also decrease. Technologies such as additive manufacturing ('3-D printing') could allow spares and other items to be manufactured where needed, further reducing the need for stock holdings. Additive manufacturing could reduce the amount of certain manufactured goods that are transported globally. However, the overall volume of material moved internationally is likely to increase due to the growing consumer class. New materials are also likely to increase the performance of vehicles, reducing the energy required for a given journey. Lighter-than-air-vehicles, for example, could significantly reduce the cost and time of transporting material over difficult terrain, such as regions with a limited road network. However, the effects of climate change are likely to have an adverse affect on most forms of transport. Warming in the Arctic is likely to lead to the melting of permafrost. In turn, this will probably adversely affect land transport, as ice roads turn to marsh. However, new Arctic shipping routes are likely to open up during the summer months.

Global passenger and freight travel growth

2010
55 trillion passenger and tonnes per km

2045
106 trillion passenger and tonnes per km



Source: Dulac, J. (2013), 'Global Land Transport Infrastructure Requirements'

The tonnage of material moved by sea is likely to double by 2045

Shanghai container terminal

Scenario:

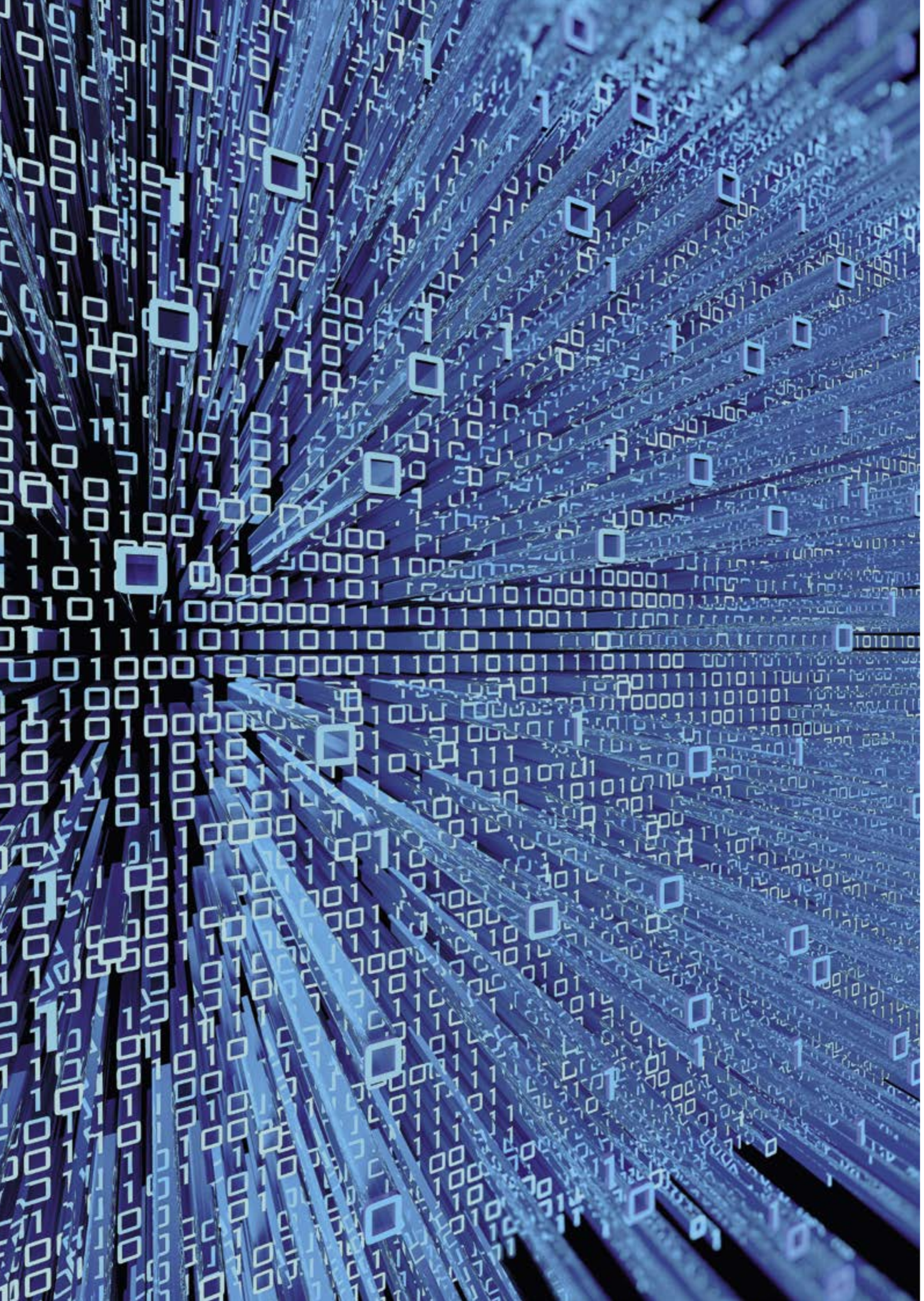
Maritime choke point

By 2045, sea lanes are likely to continue to play a major role in the global economy, despite probable advances in additive manufacturing and improvements to air and land based transport. On current forecasts, the tonnage of goods transported by sea is likely to double within the next 30 years. Anticipated growth in computing power, situational awareness and automation could mean that the shipping of goods will be quicker, cheaper and more reliable. Shipping is also likely to be safer than ever before, driven by more accurate long-range weather forecasts and improved ship construction and operating procedures. As such, a significant amount of the world's economy would depend upon maritime trade - some countries could face major financial crises if sea transport became significantly disrupted.

If tensions rose between countries near to a vital maritime choke point, particularly if threats to block the sea lane were made, the international community would almost certainly act. Countries that are likely to be highly internationally active by 2045 (such as Brazil, China and the US) could be expected to work together to try and find a resolution. Should diplomatic efforts fail to reduce tensions, the international community could approve the deployment of an international naval task force to ensure that key sea lanes were kept open. Land-based international observers could be deployed to those countries bordering the choke point and air, cyber and space surveillance of the region is likely to be intensified.

Defence and security implications

- The development of driverless vehicles could provide benefits such as safer and more reliable transport, reducing the need to put drivers and pilots, particularly of transport vehicles, into harm's way.
- Greater reliance on automated technologies could provide scope for terrorists and criminals to disrupt the transport system through cyber attacks.
- Advances in propulsion and design are likely to provide faster and more efficient transport.
- Developments such as additive manufacturing, automated inventory management and remotely piloted and unmanned transport systems are likely to bring significant efficiencies to logistics but also increase its technical complexity.



Information

Revolutionary advances in how we acquire, store and analyse information, together with dramatic increases in computer processing power, are likely to give us the ability to predict accurately a wide range of phenomena, from crime hot-spots to the effects of climate change. As everyday objects are increasingly connected to the Internet, this vast network of sensors is likely to gather data on more aspects of our lives and the environment, making it hard for anyone to go 'off the grid'.

Computational power

In 2000, the highest performing processors achieved levels of computation equivalent to that of a spider – today they are close to being as powerful as the brain of a mouse. If processing power continues to grow at its current rate (doubling every three years), by 2023 some computers could have the processing power of the human brain and by 2045 they could be 100,000 times more powerful.[1] If quantum computing becomes a reality, even these extraordinary figures could be exceeded.

The idea of quantum computing starts from the premise that quantum physics generates fundamentally novel ways of processing information, although due to the extraordinarily complex nature of this immature technology, there is little consensus on what actually constitutes a quantum computer. Initial versions of such machines are limited to performing highly specialised processes and lack the utility and flexibility of conventional computers. It is unclear when quantum machines with the usefulness of existing computers will be produced, although it is likely that this will be achieved close to or by 2045.[2]

If quantum computing becomes a reality, a key benefit could be a revolution in cyber security through harnessing quantum cryptography, to guarantee the security of a message while detecting eavesdropping. Traditional methods of securing data rely on encryption and decryption keys. Once a key is compromised, the encrypted information is accessible to all who have the key. Drawing on the fundamental properties of quantum mechanics, the secure distribution of encryption keys can be assured, as can the ability to safeguard the contents of encrypted messages. In both cases, the act of illicit 'listening-in' to the transmission changes its quantum properties rendering it unreadable. The message is protected while its interception is flagged. However, because it is in such an early stage of development, it is difficult to make any firm predictions about when the advantages of quantum computing are likely to be realised. Indeed, some experts believe that quantum computing may make all codes 'crackable' and genuine encryption impossible, as theoretically a quantum computer could try every possible combination of codes simultaneously to unlock a system. If this is the case, armed and security forces may have to physically separate their computer systems from the Internet, posing huge problems for networking and efficiency. In turn, this may result in a greater number of self-contained networks, making a

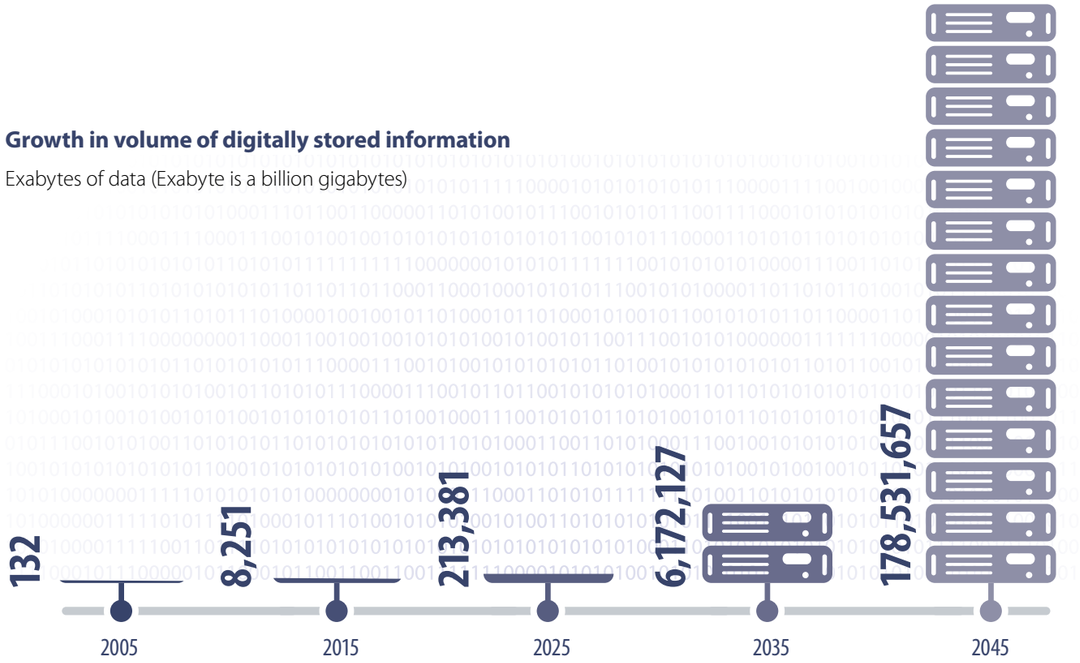
"Some experts believe that quantum computing may make all codes 'crackable' and genuine encryption impossible."

1 Time Magazine (2011), 'The Year Man Becomes Immortal', available at http://content.time.com/time/interactive/0,31813,2048601,00.html

2 DCDC research interview with Dr Simon Benjamin, Oxford University, 14 October 2013.

Growth in volume of digitally stored information

Exabytes of data (Exabyte is a billion gigabytes)



Source: Analysis by DCDC based on work by Gantz, J. and Reinsel, D. (2011) 'Extracting Value from Chaos' and EMC² (2014) 'The Digital Universe of Opportunities: Rich Data and the Increasing Value of the Internet of Things'

small contribution to slowing the current trend of greater Internet use.

Instantaneous communication opens the possibility of creating a network of quantum computers, which – regardless of their location – would be able to operate as a single system. This could generate significant advances in forecasting and modelling ability, enabling near real-time representation of complex systems, such as population dynamics, economic models and weather patterns.

'Big Data'

In 2000, 25% of the world's information was stored digitally: today it is more than 98%. On this trajectory, by 2045 there will be 20,000 times more digital information than there is today. The ability to collect and analyse this growing volume of information has been termed 'Big Data'. Such a large amount of data generates yet more information when appropriately analysed, allowing us to identify patterns which may help to counter the spread of disease, combat crime and even predict social and behavioural patterns.

Access to information has until now only let us understand the past, leaving it to people to extrapolate and imagine what this may mean for the future. Big Data is increasingly allowing us to predict future behaviours accurately. Complex data sets which contain crime records, meteorological data, and behavioural heuristics are starting to be used to map probable crime locations[3] – and in the future they are likely to deliver far more sophisticated forecasting tools. The advances in computation power mentioned previously are likely to enable further analytical processes development. This could provide the ability to model very large and complex systems more accurately to make predictions in areas such as climate change and population movements.

While Big Data could become important in helping solve some complex global issues, businesses may also become increasingly dependent on it – we are already seeing Big Data being used to predict consumer behaviours. Accountability and situational awareness are likely to increase too, as more aspects of life are quantified and analysed.

3 Friend, Z. (2013), 'Predictive Policing: Using Technology to Reduce Crime', available at http://www.fbi.gov/stats-services/publications/law-enforcement-bulletin/2013/April/predictive-policing-using-technology-to-reduce-crime

Alongside privacy issues, it is also likely to become harder to go 'off-line'. Those who do may even find that they have made themselves more conspicuous by their absence.

The 'Internet of Things'

The number of devices linked to the Internet is increasing rapidly, with everything from mobile phones to cars and even fridges having an Internet connection. This 'Internet of Things' is already a reality, with around 20 billion devices already connected,[4] rising to an estimated 40 billion by 2020. If that trajectory were to continue, there would be around 100 billion devices connected to the internet by 2045. However, increasing availability (not least because they are becoming cheaper and smaller) is likely to lead to a sharp increase in the number of connected devices, so that by 2045 there could be around 50 trillion devices connected to the internet.[5] These devices are likely to be producing and sharing vast amounts of data and information while connected to each other and to additional systems. Such a large number of devices connected across the world will almost certainly require a significant increase in communications infrastructure. The costs and technical challenges involved are likely to mean that there are some global disparities in access, at least in the short to medium term.

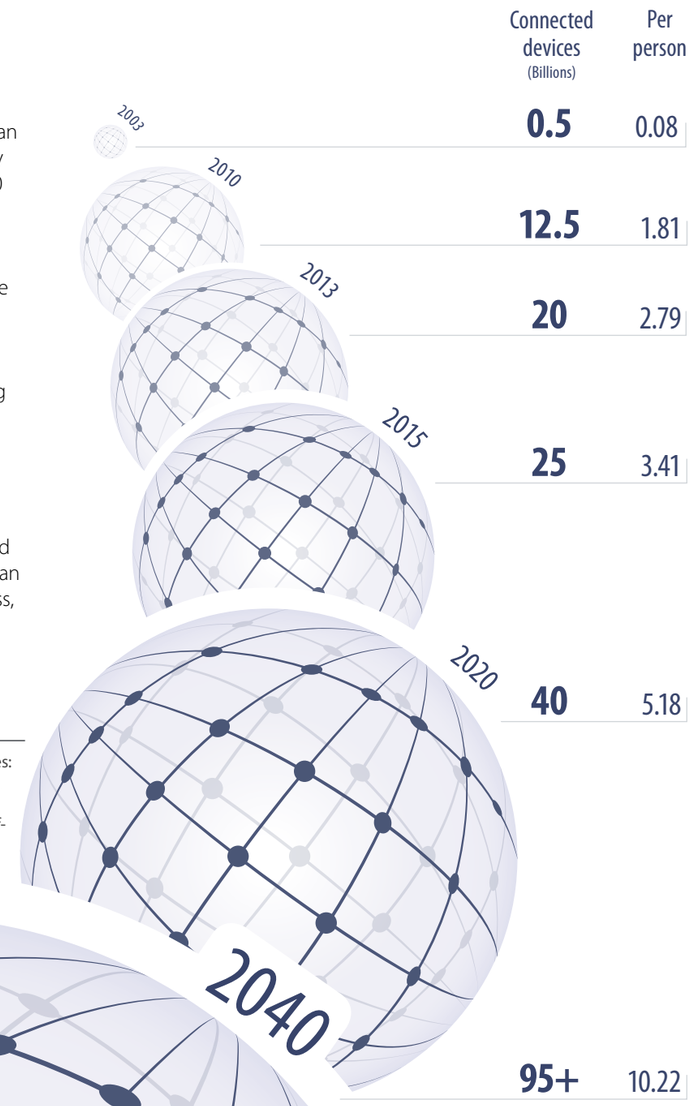
The number of Internet users is almost certain to rise, with Internet penetration and

4 EMC² (2014), 'The Digital Universe of Opportunities: Rich Data and the Increasing Value of the Internet of Things', available at http://www.emc.com/leadership/digital-universe/2014iview/internet-of-things.htm

5 Based on exponential growth forecast.

Number of connected devices

The number of connected devices has increased by 4,000% between 2003 and today. The new IPv6 internet protocol allows for **340,282,366,920,938,463,463,374,607,431,768,211,456** connections which is believed to be sufficient for the foreseeable future.



Source: Analysis by DCDC based on work by Evans, D. (2011) 'The Internet of Things', EMC2 Digital Universe with Research & Analysis by IDC and ABI Research (2013) 'More Than 30 Billion Devices'.

More sensors will intensify levels of surveillance

connection speeds continuing to improve in developed economies, facilitating remote working and further entrenching globalisation. Internet access in the Middle East and North Africa region grew by more than 2,500% between 2000 and 2012, with 40% of the world's population now online. As mobile technologies become cheaper, it is likely that sub-Saharan Africa and developing parts of Asia will see similar adoption rates. A vast increase in Internet access in the developing world could provide significant competitive advantages, as access to markets is improved and the information advantage of the developed world is equalised or even exceeded.

"The information advantage currently enjoyed by countries' defence and security forces could be eroded or even reversed."

As more of our work and social activities depend on a richly interconnected information and communications network (which may, in places, be extremely vulnerable to attack) there could be more opportunities for criminals and terrorists to have a greater impact on our day-to-day lives. Cyber bullying could also have a greater impact on our lives, as the online environment becomes increasingly socially important. Electronic communications can facilitate harassment, with online users writing comments that they would be unlikely to say in person. Anonymity could also lead to a greater propensity for malicious gossip, witch-hunts and hate-campaigns, potentially leading to rapid escalation of issues. Similarly, electronic media allows small, technologically-savvy interest groups to have a disproportionately loud voice. This could further the rights of under-represented minorities but may also lead to polarization as extreme views are exchanged and reinforced in forums where dissenting voices are absent.

People in many parts of the world are used to having mobile phones and computers with Internet connections, but by 2045, it is likely that numerous objects will contain some kind of sensor. There will probably be ubiquitous, tiny and cheap monitors reporting on the quality of drinking water, detecting structural damage in buildings and vehicles, and sensing and measuring pollution in the environment. Machinery and consumer products are likely to be monitored for the state of their components and materials, enabling them to report when repair or replacement is necessary. With progress in nanotechnology, vast networks of security sensors could provide continuous monitoring of critical infrastructure (such as buildings, bridges and pipelines),[6] detecting chemical and biological attacks.[7] The fusion of data from a range of sensors, combined with inputs from public sources such as social networking sites, will probably improve profiling and tracking capabilities. Stealth vehicles are likely to find it more difficult to remain hidden and the ability to prosecute covert operations, particularly in urban environments, is likely to become more technically challenging. As the number of connected public sensors increases, the information advantage currently enjoyed by countries' defence and security forces could be eroded or even reversed as adversaries, including non-state actors, attain similar levels of situational awareness.

The uptake of social networking sites and even the use of supermarket loyalty cards shows that – for comparatively small rewards – people are readily persuaded to record their movements, financial transactions and buying habits. This behaviour is highly likely to continue out to 2045. National authorities are almost certain to seek to use this potential mine of information – a development that is likely to raise major privacy concerns.[8] Marketing campaigns are likely to portray the benefits of smart technology and machine-to-machine interaction, but the increased surveillance capability may make others fear an increase of state control. In turn, this is likely to drive the growth of the 'hactivist' community characterised by groups such as Anonymous.[9] However, it is likely to be increasingly difficult to avoid the sensor network of a future 'Internet of Things', since even remote environments are likely to contain some connected devices. A desire not to be part of the 'Internet of Things' may create new markets, for example a holiday resort advertising its facilities as literally 'getting away from it all' with a promise that you will be completely 'off-grid'. This could also lead to a drive to try to create spaces, both physical and virtual, which are unseen or ungoverned by state authorities around the world.[10]

6 Foresight Horizon Scanning Centre Sigma Scan 2.0 (2009), 'Nanosensors for Innovative Sensing Applications', available at http://www.sigmascan.org/Live/Issue/ViewIssue/527/5/nanosensors-for-innovative-sensing-applications/

7 *Ibid.*

8 Defence Science and Technology Laboratory (2012), 'Mass Surveillance'

9 Kelly, B. (2012), 'Investing in a Centralized Cybersecurity Infrastructure'

10 As predicted by Social Identity Theory. See Tajfel, H. and Turner, J. C. (1986), 'The Social Identity Theory of Intergroup Behaviour'

Defence and security implications

- Quantum computing could make all codes 'crackable' and genuine encryption impossible, as a quantum computer could theoretically try every possible combination of codes simultaneously to unlock a system. If this is the case, armed and security forces may have to physically separate their computer systems from the Internet, posing huge problems for networking and efficiency. Alternatively quantum cryptography could guarantee security of a message.
- Better gathering and analysis of data could vastly improve our understanding of physical and virtual environments. Predicting crime hotspots could enable more targeted deployment of police officers. Greater awareness of deficits and surpluses may make logistics more efficient. Similarly, detailed and rapid analysis of social networks could provide a deeper understanding of the local population, its culture and the environment.
- As more of our work and social activities depend on interconnected information and communications networks – which may, in places, be extremely vulnerable to attack – there could be more opportunities for criminals and terrorists to have a greater impact on our day-to-day lives. Similarly the ability to keep secrets is likely to become increasingly difficult.
- Connectivity of assets with strategic importance (such as those relating to national infrastructure) is likely to increase. Although this is likely to lead to gains in efficiency, it may also make such assets more vulnerable.
- An increasing number of devices capable of collecting sensor data could intensify levels of surveillance. Stealth vehicles may find it more difficult to remain hidden and the ability to prosecute covert operations, especially in urban environments, is likely to become more technically challenging. This is particularly significant given the probable increase in the size of urban areas, along with the growing use of surveillance to prevent crime.
- As the number of connected 'public' sensors increases, the information advantage currently enjoyed by countries' defence and security forces could be eroded or even reversed as adversaries, including non-state actors, attain similar levels of situational awareness.

Education

Increasing computing power, growing access to the Internet and 'Big Data' are likely to have a transformative effect on education, with an increasing blurring between online and offline learning. Education levels will almost certainly continue to rise across the globe and for both sexes. At the same time, educational institutions could face a series of major challenges, including facilitating smoother transitions from education to work and encouraging lifelong learning to ensure the workforce can adapt to a changing job market. These pressures may force educational institutions to provide more informal, distance and personalised learning. There is likely to be a growing emphasis on the transferability and constant upgrading of qualifications, as well as a shift towards more personalised forms of assessment that use a range of technologies to trace the paths of individual learners.

Technology's impact on education and skills

Significantly increased computing power seems likely to be available on demand at greatly reduced cost over the next three decades. Teachers are likely to have access to vast quantities of data, and could have the facility to command the flow of information and learning in their classrooms by controlling the exercises, simulations and games, in which their students participate, at the touch of a button. Books will almost certainly be more widely available online – as e-book technologies evolve, they seem likely to offer new ways of interacting with shared, adaptive, dynamic and multimedia publications. As 'Big Data' changes our understanding of the world, developing data analysis and computing skills are likely to become increasingly central. For example, social science students are likely to increasingly examine social phenomena using computer models and data rather than just fieldwork. As school teaching becomes more online and software-based in nature, existing educational inequalities could be exacerbated, as not everyone is likely to have the same level of digital access.[1] However, it is likely that online learning will continue to make education more accessible, particularly for people who are geographically isolated.

Education courses, particularly at university level, are likely to depend increasingly on the Internet, with some delivered exclusively, or almost exclusively, online. Digitally-delivered education could also provide increasing personalisation, with students able to customise when, where and how they learn. While face-to-face teaching in the classroom is unlikely to disappear, it is likely to become increasingly focussed on simulation, interactive games and debate rather than traditional classroom-based learning. Teachers' primary roles are likely to become that of learning adviser, helping students navigate their own education rather than providing it all themselves.

1 Facer, K. (2011), 'Learning Futures: Education, Technology and Social Change'; Sharples, M. *et al.* (2012), 'Innovating Pedagogy 2012'; Stoyanov, S. *et al.* (2010), 'Mapping Major Changes to Education and Training in 2025'

Blending formal with informal teaching

The capacity to manage and mobilise social networks will almost certainly be an increasingly important skill-set to possess, with growing demands on educators and employers to build this capacity. Research shows that people learn best with, and from, others. Therefore, as social networking evolves, there may be more collaborative learning, with online networks offering real-time discussion and virtual classrooms.

The 'Internet of Things' is likely to allow data from the classroom to be used for continuous performance management. Networked devices are likely to combine with cheap data storage to open up new accountability, scrutiny and reporting practices. New tools could permit students to share comments about their education in public forums, opening up new ways of holding teachers to account. Students and teachers may feel increasingly scrutinised, with some positive benefits – such as detailed, sophisticated and real-time feedback on performance – and many negative, such as a decline in social skills.[2] Already sites like 'RateMyTeachers' are beginning to challenge old power relationships and underpin new ones, and they are likely to become even more widely used in new and sophisticated ways.[3]

Restructuring traditional education systems

As research reveals more about the psychology of education, so learning is likely to increasingly be packaged in a way that blends the formal with the informal. Line managers in the workplace may take on increasing responsibilities as 'learning advisers' for their staff and, as workplace learning and development becomes more ongoing, social and informal, organisations are likely to run extensive programmes of coaching and mentoring as a core element of their learning and development programme. As informal and social learning grow in importance, individuals may increasingly look for ways for this learning to be recognised or accredited to demonstrate their value in the marketplace.[4]

Educational institutions may be increasingly organised (and classes brought together) on the basis of common knowledge, skills and preferred learning and teaching styles rather than (just) age. Educational programmes are also likely to include elements dedicated to developing students' skills in learning. Research highlighting the importance of creativity in underpinning academic and business success may stimulate a new focus on developing students' creative skills at school and university. Cognitive testing may have developed to such an extent that its results replace qualifications and experience assessment as the major element in the recruitment process. It is possible that, by 2045, hiring decisions will become (almost) entirely based on cognitive tests rather than qualification levels. [5]

2 Facer, *op. cit.*; Cliff, D. *et al.* (2008), 'Future Issues in Socio-Technical Change for UK Education'

3 Facer, *op. cit*; Castells, M. (2009), 'Communication Power'; Taylor, E. and Sheehan, T. (2010), 'Perspectives on the Future of Learning'

4 *Ibid.*

5 Facer, *op. cit.*; Fairhurst, P. (2010), 'Learning and Development: Perspectives on the Future'

As the future workforce, at least in developed countries, is recruited increasingly from an older population, so the need for an improved lifelong training and education system could increase. Educational providers may aim short and online courses at lifelong learners, and sabbaticals could become increasingly popular as a means of refreshing one's learning in a fast-paced world. Educational entrepreneurs are likely to recognise that there is a huge market among middle-aged people wanting to upgrade their knowledge and older people wanting to pursue second careers. Simultaneously, as the world's population ages, and as education becomes more informal and less institutionally based, so the family home could become a more critical educational space. As opportunities for education increasingly occur at home, away from the classroom, so grandparents and great-grandparents could be more crucial to its delivery. As older people mix work and care later in life, they may become partners in learning alongside their own children and grandchildren. It is already common to find grandchildren acting as teachers for grandparents to introduce them to digital technology, and other precedents can be found in the roles played by younger children in citizenship education and adjusting older family members following migration. As the twenty-first century nears its mid-point, educational institutions may become cross-generational hubs of learning, with older family members actively involved in passing on their learning to the younger generations and, in turn, picking up new ideas and skills from them.[6]

The global education marketplace

Institutions in Europe, Northern America and Australia may increasingly run their highest quality programmes from campuses in developing countries, as well as introducing more distance-learning courses. As more people learn outside their country of origin, and migrate to pursue careers, it is likely that there will be a drive to standardise qualifications at the global level. Even if a common global curriculum is not universally pursued at secondary school level – as an extension and expansion of the International Baccalaureate, for example – it is probable that qualifications will be defined as part of a common global system.[7] Across the developed world, many schools are likely to be increasingly run (or at least sponsored) by powerful corporate organisations or by parent groups. There may be much-reduced government oversight and involvement.

Educational inequalities

Global gender gaps at the primary school level are likely to have largely disappeared by 2045,[8] although girls are likely to remain under-educated in many of the world's most intractably poor countries. This trend is likely to be strongly evident in those countries where cultural and religious factors (such as some interpretations of Islam) constrain women from taking part in education and the economy. Access to education could also become more polarised, depending on wealth or ability to pay. Students may be separated into vocational and academic streams from a young age. As corporate involvement in education grows it may encourage children's entry to one or other stream at even earlier ages, as corporations and organisations (including the armed forces) seek to identify – and train accordingly – the strongest future performers.[9]

The average level of educational attainment is highly likely to rise, shrinking the gap between developing and more developed countries. Countries like Bangladesh, India, Pakistan and Nigeria are projected to raise the average years of schooling of their workforce by about three years over the next three decades. However, the average number of years spent in full-time education is likely to remain at current levels in well-educated workforces. In more advanced developing countries, women's participation in formal education is likely to increase

"As education becomes more informal and less institutionally based, so the family home could become a more critical educational space."

6 Facer, *op. cit.;* Fairhurst, *op. cit.*

7 Stoyanov, S. *et al.* (2010), 'Ten-Year Forecast'

8 Beck, B. (2012), 'Women's World'; Dickson, J. R. *et al.* (2010), 'Patterns of Potential Human Progress'; Dorling, D. (2013), 'Population 10 Billion'

9 Facer *op. cit.*; Watson, R. (2010), 'Future Files: a Brief History of the Next 50 Years'; Benn, M. (2011), 'School Wars: the Battle for Britain's Education'

Part 1

Gender gaps within schools are likely to have largely disappeared by 2045

considerably. By 2045, it is possible that a majority of the world's children will have had a university or higher-level education.

Machines, jobs and education

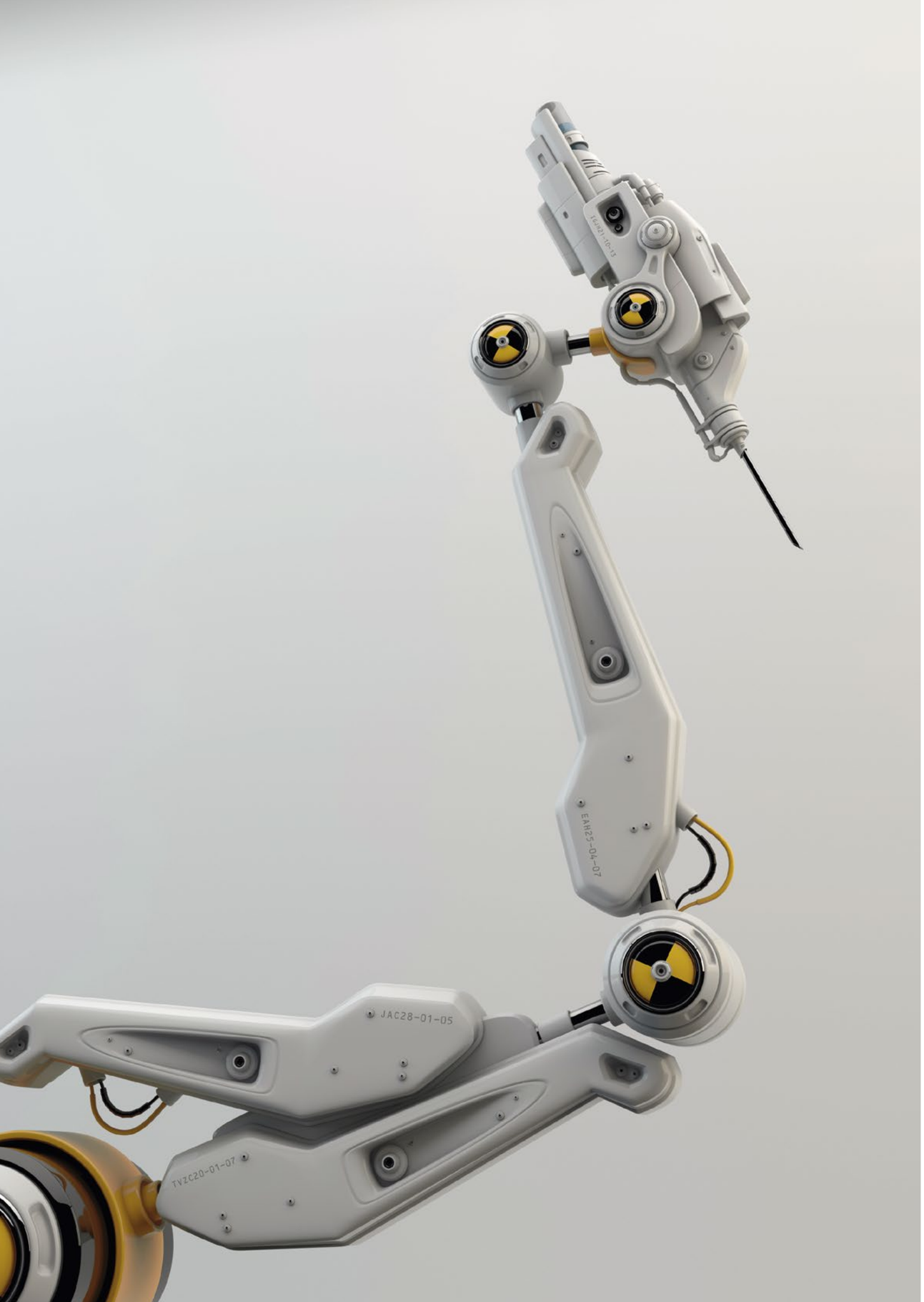
Machines are likely to take over certain jobs from people, with developments in artificial intelligence ultimately meaning that education could focus on those (few) areas of human thought and activity that machines are unable to deliver efficiently. This means that education may play an important role in enhancing people's ability to develop new ideas, to interact empathetically with other people and to take responsibility – all things that it is difficult to envisage machines doing by 2045.[10]

10 Facer, *op. cit.*; Cliff *et al.*, *op. cit.*; Watson, *op. cit.*

Defence and security implications

- Global education levels are likely to increase, but educational inequalities will probably persist, entrenching social discontentment and allowing youth disaffection to continue.
- In the new education and training mix facilitated by employers, online and virtual blended learning are likely to predominate, though formal face-to-face learning is unlikely to die out completely.
- Some countries may begin to educate and train children assessed as having the potential to succeed in specific careers (including in the armed forces) from a very young age.

Global Strategic Trends



Automation and work

Robots or 'unmanned systems' – machines capable of carrying out complex tasks without directly involving a human operator – are likely to be as ubiquitous in 2045 as computers are today. Unmanned systems are increasingly likely to replace people in the workplace, carrying out tasks with increased effectiveness and efficiency, while reducing risk to humans. This could ultimately lead to mass unemployment and social unrest. As robots become more lifelike, perhaps capable of appearing to express emotion, interactions with people are likely to become more sophisticated. The increased capability of robots is likely to change the face of warfare, with the possibility that some countries may replace potentially large numbers of soldiers, sailors and airmen with robots by 2045. However, military decision-making is likely to remain the remit of humans for ethical reasons, at least in western countries. Others may not be so willing to make the same trade-offs between speed and accountability.

The proportion of older workers in the global labour force is likely to increase out to 2045, with a possible corresponding decrease in opportunities for younger people. Flexible working practices are likely to become more widespread, with people employed on shorter-term contracts and a growth in working remotely. Workers will probably have less predictable income and increasing economic insecurity. By 2045, there is likely to be greater equality between men and women in the jobs market, particularly in the developed countries. In part, this may be driven by a global shift away from manual labour, towards a more knowledge-based economy.

Robots in the workplace

Robots are increasingly likely to replace people at work, which could ultimately lead to social unrest. Robots are likely to continue to carry out tasks deemed too dirty, dull or dangerous for people, and will probably be used more extensively in such roles, as well as for more highly-skilled jobs. As robots become increasingly sophisticated, they are likely to perform tasks which would otherwise put people at risk, such as minefield clearance. By 2045, it is even possible that robots will take on combat roles. Non-military jobs such as fire-fighting or construction are also likely to be carried out by machines in the future. In the same way that the widespread use of computers has made some professions (such as typists) almost redundant, we can expect robot development to remove a number of types of job that are common today.[1] While advancements in robotics may create new jobs that we have not yet envisaged (just as web designers were not imagined in the 1980s), adapting workers to a new set of roles may take considerable time, causing problems in the interim. While it is possible that governments will legislate to try to prevent the employment of robots in some areas, to safeguard human jobs, it is not clear how effective this would be in the face of market forces. It is also unclear whether new jobs will be created at a rate sufficient to replace those that are lost. As some automated processes become cheaper than even the lowest-paid

"By 2045, it is even possible that robots will take on combat roles."

1 Lin, P., Abney, K. and Bekey, G. (2011), 'Robot Ethics: Mapping the Issues for a Mechanized World'

human workers, it is possible that there will be a rebalancing of global manufacturing economies.

Additive manufacturing

Global manufacturing is currently evolving from a highly labour-intensive process towards more information technology-based processes.[2] This is, in places, driving a trend towards manufacturing processes relocating closer to their consumers, to avoid long supply chains. This could affect the balance of manufacturing in the developed and developing world, with less need for conventional manufacturing jobs in many regions.[3] Automation already facilitates this trend, and we expect to see additive manufacturing (more commonly known as '3-D printing') also making a significant contribution. Additive manufacturing has the potential to transform the manufacturing industry, with performance and cost-effectiveness rapidly improving to the point where large-scale adoption for manufacturers is plausible well within the 2045 timeframe. 3-D printing enables on-demand production, allowing items to be created quickly when an order is placed, rather than large amounts of costly stock having to be held in readiness for prolonged periods. With more decentralised production, products could be designed and printed for local consumption, potentially reducing reliance on expensive imports and requiring less industrial infrastructure than conventional manufacturing. It is also likely that personal use of 3-D printers will increase rapidly, allowing for unprecedented levels of mass customisation and even the 'democratisation' of manufacturing, as consumers and entrepreneurs begin to print their own products.[4] By 2045, additive manufacturing systems could be a common feature in the home and be capable of producing a wide range of outputs – food, clothing, and even complex devices with mechanical and electronic components.

"Developments in robotics may mean that robots are almost physically indistinguishable from human beings."

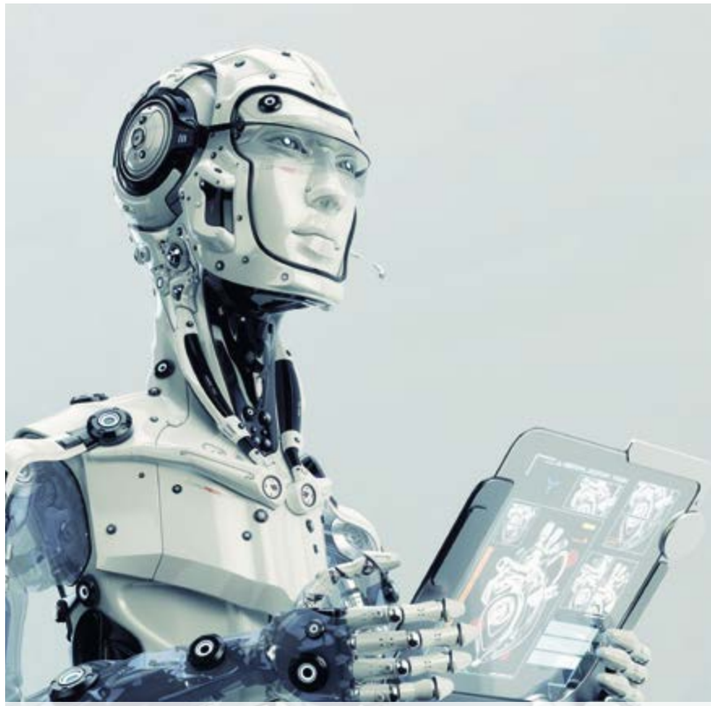
Additive manufacturing is almost certain to enable the production of a wide range of illicit objects, although it seems unlikely that, by 2045, additive manufacturing systems will be able to replicate complex chemical components, such as propellants for ammunition.

More life-like machines

A growing number of customer-service roles are likely to become automated or be performed by robots. Over the last century, industrial processes have shown how automation can dramatically increase productivity, while lowering cost. This trend will probably continue, with increasing automation of service roles, such as telephone or Internet-based customer support. By 2045, advances in artificial intelligence are likely to mean that such services could be enhanced to the point that a virtual telephone operator would be indistinguishable from a human one. There is also likely to be an increasing shift towards mechanising caring roles, particularly in areas where there are few human candidates. Japan is developing pioneering robots that can provide care for the elderly, driven partly by its ageing population and shrinking workforce.[5] Using robots as companions is also likely to increase in the timeframe. For example, Japan is experimenting with using robot companions for its astronauts in space,[6] and robotic pets and computer programmes with simulated personalities are growing in popularity.

Eventually, developments in robotics may mean that robots are almost physically indistinguishable from human beings, but it is hard to believe that by 2045 they will have achieved the degree of social acceptance or skills necessary for them to operate in all roles. For example, jobs that require a human face will probably remain a human preserve, as will roles that require the display (or at least appearance) of emotion. Although demonstrating the appearance of realistic emotion is likely to endear robots more to humans, this could create its own problems, with people potentially becoming emotionally attached to machines. Such a phenomenon has arguably already been experienced by a small sub-set of computer-users' feelings towards virtual characters,[7] and may be particularly problematic in the case of children forming emotional attachments to robot carers. The implications of human-machine relations are not yet known, and even by 2045, the long-term effects may not be clear.

Technological advancements are almost certain to provide increasing levels of robotic automation, improving efficiency, speed of response and ease of use. By 2045, it is likely that there will be many more robots that are able to perceive their environments, make limited decisions and take action for themselves. The level of responsibility given to such robots is likely to be determined by the importance of the roles they are intended to be used for and, more significantly, how willing we are to trust them.[8] This trust is likely to largely depend on how well robots perform the tasks they are instructed to do, and how well they are able to learn.



An increasing shift towards mechanising of caring roles

Research, regulation and health

Research into, and development of, unmanned systems will probably be increasingly commercially led. How unmanned systems develop is likely to depend, to a considerable degree, on how they are funded. Building large or highly complex robots – such as those used for surgery – can be extremely costly, while the decreasing cost of many technological components makes developing smaller or simpler robots more affordable. This may impact on which countries or companies carry out cutting-edge research. The US Government may lead on robotics for military usage, while Japanese companies are currently at the forefront of developing robots with commercial applications.[9]

As robots become more sophisticated, taking on a wider range of responsibilities, novel legal questions will almost certainly emerge. For example, when robots malfunction, is it the owner, manufacturer or programmer who is responsible? Does a robot with biological components have rights? Changes to legislation will almost certainly be required, but past experience suggests it is highly likely that legislation will fail to keep up with the speed of technological developments.

Surgery and surgical implants of the future are likely to be less invasive and more effective. By 2045, robots will almost certainly be able to respond to fast-moving or microscopic environments far better than humans, due to their faster information-processing times,[10] enhanced precision and lack of susceptibility

2 RAHS Vanguard (2013), 'Rising Robotics and the Third Industrial Revolution'

3 National Intelligence Council (2012), 'Global Trends 2030: Alternative Worlds'

4 *Ibid.*

5 Lin, *et al.*, *op cit.*

6 Sky News (2013), 'Robot Astronaut Kirobo Calls Home From Space', available at http://news.sky.com/story/1137583/robot-astronaut-kirobo-calls-home-from-space

7 Rani, A. (2013), 'The Japanese Men Who Prefer Virtual Girlfriends to Sex', available at http://www.bbc.co.uk/news/magazine-24614830

8 Singer, P. W. (2009), 'Robots at War: The New Battlefield'

9 Lin, *et al.*, *op. cit.*

10 Parasuraman, R. *et al.* (2007), 'Adaptive Automation for Human-Robot Teaming in Future Command and Control Systems'

to human weaknesses, such as fatigue or hand-tremors. This is highly likely to lead to new possibilities for medicine, such as eventually removing human surgeons from operating theatres, diagnoses performed by robots travelling along the bloodstream and operations performed at a cellular level. Some experts suggest that robots will eventually be small enough to fit inside a single living cell, capable of repairing damaged DNA or acting as antibodies against viruses/infections, although it is unclear whether or not such technology will be available by 2045.

Automation and conflict

The increased capability of robots is likely to change the face of warfare. Improvements in robotics have obvious applications for military usage. Unmanned naval vessels – possibly reconnaissance submarines to probe a hostile shore – are likely to become as much a part of the military system as unmanned and remotely piloted platforms have in the air. Machines are likely to carry out tasks, such as minefield clearance and delivering supplies across hazardous areas, although the highly complex nature of these tasks may mean that driverless military vehicles lag behind their civilian counterparts. There may also be a drive towards replacing infantry soldiers with robots, as society becomes less willing to accept death or injury in warfare. In 2045, it is likely to continue to be much more palatable to put a machine in harm's way, rather than a human soldier. Some experts believe that robots will begin to replace infantry soldiers for some developed-world militaries within the next ten years.[11] The extent to which military personnel will be replaced by automated systems within the 2045 timeframe is unclear. However, robots are likely to work in collaborative human/machine teams, similar to the way that dogs and their handlers currently operate.[12] Western countries are likely to continue to keep humans in the decision-making loop for ethical reasons, although others may not be so willing to make the same trade-offs between speed and accountability. If combat is primarily conducted by machines, with much less human involvement, it may become more publicly and politically acceptable, and potentially more likely.

In the future, a sophisticated robotic 'army' could theoretically be operated by a single individual, giving that person enormous power. Authoritarian regimes may therefore find it easier to stay in power, at least in the face of internal uprisings. Similarly, using robots could significantly amplify the capabilities of small groups of insurgents or terrorists, thereby increasing the threat that they present.

Age inequality in the workforce

The proportion of older workers in the global labour force is likely to increase, with a possible corresponding decrease in opportunities for younger people in some areas. The retirement age in many western countries is rising and looks set to continue doing so, driven by an increase in life expectancy, improvements in health and the rising cost of supporting older people who are not working. Several estimations indicate that the number of people aged 60 and over in the EU working-age population will increase by about 0.5% a year over the next 30 years.[13] Some members of this older workforce may not possess the digital and high-tech skills that many jobs are likely to require. Nevertheless, they are likely to have the expertise in management and customer relations that may enable them to remain in comparatively well-paid employment, which may block younger workers from satisfactory career progression. This could create an uncertain and frustrating working life for some younger people, who may be cut off from financial stability while simultaneously being provided with increasing amounts of information (via growing access to the Internet) about the financial security enjoyed by others. The economic disenfranchisement of young people is likely to be particularly problematic in those regions and countries (most notably sub-Saharan Africa, the Middle East and India) which are likely to have sizeable youth populations. However, this may be counterbalanced to some extent by the higher numbers of young people who become entrepreneurs or are employed in the new technology enabled jobs that are likely to appear – rather like the jobs in web design and social media marketing that have appeared in the past couple of decades.

> *"Some experts believe that robots will begin to replace infantry soldiers for some developed-world militaries within the next ten years."*

11 Singer, *op. cit.*

12 *Ibid.*

13 Bell, D. N. F. (2013), 'Older Workers and Working Time'

Scenario:

Large-scale automation of work

Robots and automated systems have the potential to be near-ubiquitous in 2045, capable of carrying out extremely complex tasks with no human involvement. Potentially, machines could: carry out all manufacturing and agricultural tasks; repair themselves; as well as clean, cook and tidy. Advances in artificial intelligences could make machines so life-like that they are able to answer phones in call-centres, take care of children and even teach. Computers could potentially diagnose and treat almost every medical condition. If progress on this scale is made in the future, it is possible that there would be very few jobs still carried out by human beings, who could, in practice, be almost totally excluded from the workforce.

In richer countries, this large-scale automation of work would be likely to have a mostly positive effect, as governments would probably be able to provide their citizens with all the material comforts they need. However, many people may initially struggle to achieve a sense of purpose and social status without work, with possible rises in cases of depression. Education systems may need to be totally redesigned to enable people to self-motivate and to gain satisfaction from activities other than work. Over time, when populations had become more used to a life without work, they may fill their time playing sport, painting, reading and composing music.

In poorer countries, however, large-scale automation of work could stall economic development, perhaps even reversing it. For example, foreign companies would be far less likely to employ cheap labour, as machines would be so much more cost-effective and efficient. Some employment could initially remain, as poorer countries would be less likely to afford to use machines to carry out roles in their internal labour markets. Eventually, though, automated equipment would probably become cheap enough for even these countries to afford. Poorer governments may not be able to provide more than an extremely basic level of subsistence, meaning that people would have no way to improve their living conditions. This could lead them to become deeply frustrated and angry. Nevertheless, citizens would still receive some benefits from large-scale automation, such as charity-funded machines capable of providing very cheap diagnosis and treating disease. Mass protests and civil unrest could still develop, with 'anti-robot' movements becoming increasingly powerful.

Flexible working

Flexible working practices are likely to become more widespread, potentially increasing economic insecurity. It is highly likely that developments in information and communications technology will make remote working more feasible. Consequently, there are likely to be smaller and fewer permanent workspaces, with increasing use of working hubs, hot desks and teleconferencing. Organisations are also likely to have an ever-smaller pool of core full-time employees for fixed functions, with the majority of workers employed on short-term contracts, allowing employers to adapt more readily to ebbing and flowing demand. These flexible working practices may let employers operate more efficiently in an increasingly uncertain, unpredictable and competitive business environment. While some workers are likely to welcome the increased freedom that more variable employment brings, others are likely to resent the insecurity caused by an unpredictable income.

Gender and work

There is a global move away from jobs requiring heavy manual labour, with a corresponding shift towards a knowledge-based economy, in which women and men are likely to be able to perform on more equal terms. Women are also less likely than men to emigrate for work. However, they are more likely to be mobile within their own country, providing economic benefit to their country of origin rather than exporting that expertise.[14] Improved information and communications technology could render geographical location less important, making women more able to access the workplace while caring for dependents.

The stigma attached to fulfilling opposite gender roles may decrease. Men are likely to readjust their aspirations to suit a more gender-equal workplace, as it becomes more normal for women to have long-term careers. However, some men may find it difficult to adjust their career aspirations and adapt to a domestic role, with women still being more likely to care for dependents in 2045. It is likely that there will continue to be professions preferred by one gender over another, and 50/50 representation in all careers is unlikely. In most western cultures, the 'glass ceiling' is likely to increasingly be replaced by a 'glass funnel'. Gender may still play a role in filtering people for the most high profile jobs, but there will probably be increasing paths to the top for women in most professions. It is likely that the aperture of the 'glass funnel' will widen in the 2045 timeframe, and that women's representation at higher levels of society, politics, industry and in the military will increase.

14 Docquier, F. (2008), 'Are Skilled Women More Migratory than Skilled Men?'

Automation will drive a move away from jobs requiring heavy manual labour

Defence and security implications

- Automated manufacturing techniques and practices may lead to economic destabilisation, as there is less need to use cheap labour. This may disproportionately affect emerging economies that would otherwise have benefited from out-sourced production arising from inexpensive labour.
- There may be public mistrust of, and resistance to, using unmanned systems (and robots in particular).
- Unmanned systems are likely to have an increasing role in combat, potentially transforming the way that wars are fought. Military decision-making is likely to remain a human preserve, at least in western countries, but it is possible that the actual fighting will no longer be a solely human endeavour.
- There is unlikely to be global legal and ethical agreement on the way in which military unmanned systems should be employed.
- If combat is primarily conducted by machines, with much less human involvement, it may become more publicly and politically acceptable, and possibly more likely.
- The cost of unmanned systems is likely to fall, while the ease of manufacturing complex items rises, making unmanned systems much more widespread and harder to regulate. Criminal and terrorist groups are likely to find it easier to gain, hold and use unmanned capabilities.

Corruption and money

If unchallenged, corruption is likely to continue to exacerbate global inequality and conflict. By 2045, consistent attempts to curtail corrupt practices are likely to be made by national governments, international governing institutions, the private sector and non-state actors. Technology is highly likely to play a significant role in both enabling and combating corruption.

State-backed currencies will almost certainly still be the dominant form of money in 2045, although alternative currencies are likely to expand, constituting the main shift in the financial landscape. Criminal transactions may increasingly be made using alternative currencies, with a possible growth in the anonymous raising and transferring of funds by terrorist groups. Governments could have less influence over alternative currencies and, as a result, may be less able to shape the global financial system or raise revenues through taxation. A single international currency within the timeframe is improbable, with the US dollar likely to remain the most important global currency by 2045. China is likely to allow greater financial liberalisation, contributing to its possible overtaking of the US in terms of GDP within the next 30 years. This is likely to be a factor in some erosion of the pre-eminence of the dollar as the dominant global reserve currency. Increased globalisation could also make transmission of financial shocks more widespread.

Defining corruption

Tackling corruption is particularly difficult because there is little global agreement on what it is. While most people have a sense of what 'corruption' means to them, this often varies between countries. What constitutes corruption in one country may be entirely culturally acceptable in another – political lobbying is seen as corrupt in Brazil but normal in the US, while the UK Parliament is debating whether to regulate it further. Social norms and perceptions of what constitutes corruption are likely to continue to change, although once a society labels a practice 'corrupt' it rarely goes back to being deemed acceptable. The poor are likely to continue to be disproportionately affected by corruption, contributing to rising inequality and potential civil unrest. For example, although they are most in need of government services, they are often unable to pay the bribes required to access them.

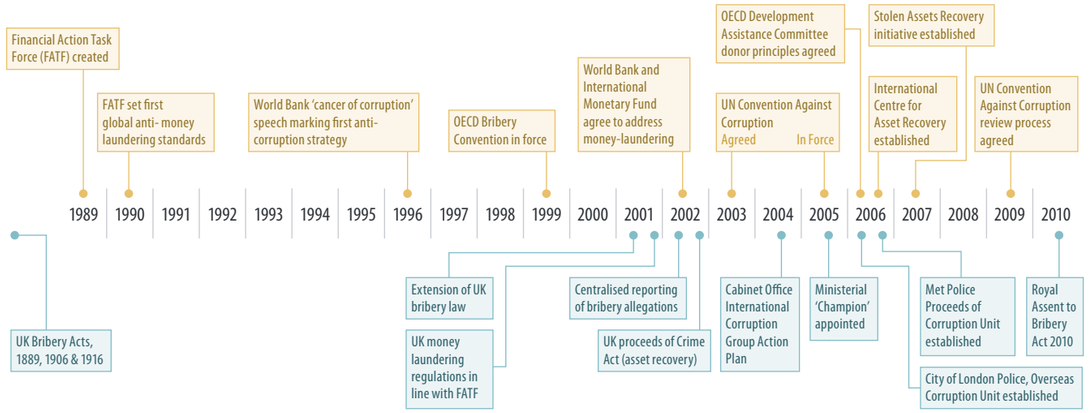
The potential for corporate corruption may increase as multinational corporations grow in prominence and economic reach. Political party funding and lobbying by industries and interest groups are also likely to be key aspects of the debate around corruption over the next 30 years. Some countries may seek to promote more transparency and regulations in lobbying to prevent informal or illegal practices. Police and judiciaries in many countries are likely to continue to become more transparent, reducing overall levels of corruption. Where these authorities have entrenched corrupt practices, efforts to complete institutional and cultural reforms will probably be impeded.

Responses to corruption

There is already an acceptance today that corruption needs to be addressed, but it is likely that by 2045 this will have become even

"The potential for corporate corruption may increase as multinational corporations grow in prominence and economic reach."

Anti-corruption legislation



more widespread. Global efforts to counter corruption are likely to continue to develop, probably in an increasingly international and collaborative way, underpinned by treaties and formal agreements. While some corporate governance practices already address corruption, it is likely that by 2045 there will be more nuanced approaches taken to ensure greater transparency in the activities of the state. Reform is likely to be slow, as strong governance institutions and cultural reforms take time to establish. For example, while democracy is correlated with significantly lower levels of corruption, this only applies after democracy has been in place for a number of decades. With corruption still likely to be endemic in some countries by 2045, there may be an increased focus on foreign direct investment as an alternative to aid provided through governments.

"The shift towards online banking and finance may simply alter the vehicle of bribery, with unregulated, non-state-backed currencies being used to avoid scrutiny."

Technology and corruption

Technology is likely to have both a positive and negative impact on corruption. The growing number of Internet users – an estimated three billion today[1] – together with the accessibility of 'Big Data' and ever-expanding digital and social media to share information and organise campaigns, is likely to drive dialogue between the citizen and state and promote state accountability. For example, the UK has already been required to demonstrate public transparency over the beneficial ownership of companies. There might be greater transparency over corporate ownership and the risks of money laundering even before 2045. Whistle-blowers are likely to increasingly use cyberspace as a publishing platform and may demand more protection when they reveal corrupt practices. However, it may be easier to hide payment of large bribes in the vast datasets that increased global connectivity produces. The shift towards online banking and finance may simply alter the vehicle of bribery, with unregulated, non-state-backed currencies being used to avoid scrutiny.

Criminal transactions are likely to be increasingly made using alternative (non-state-backed) currencies, potentially making it easier for illegal groups to transfer funds between jurisdictions. The potential for individuals to make anonymous payments (bypassing laws and avoiding tax), along with a lack of central control and regulation makes alternative currencies such as Bitcoin, Litecoin or Ripple attractive for criminal use. When the founder of a website associated with the sale of narcotics and firearms ('the Silk Road') was detained by US authorities in October 2013, the value of Bitcoin fell sharply. Some commentators have suggested that this incident illustrates the impact that criminal users have on the value of the currency.[2] This view is reinforced by a recent study which showed that daily sales on the Silk Road website corresponded to approximately 20% of the activity on the main Bitcoin exchange.[3] It is likely that non-state-backed currencies will continue to be used as a means of payment for online criminal activity. It is also possible that terrorist groups could adopt such currencies as a means of fundraising or transferring funds anonymously – governments are, of course, likely to try to monitor the use of these currencies.

1 Lagarde, C. (2014), 'A New Multilateralism for the 21st Century: The Richard Dimbleby Lecture'

2 Hern, Alex (2013), 'Bitcoin Price Plummets After Silk Road Closure', available at http://www.theguardian.com/technology/2013/oct/03/bitcoin-price-silk-road-ulbricht-value

3 Christin, N (2013), 'Travelling the Silk Road: A Measurement Analysis of a Large Anonymous Online Marketplace'

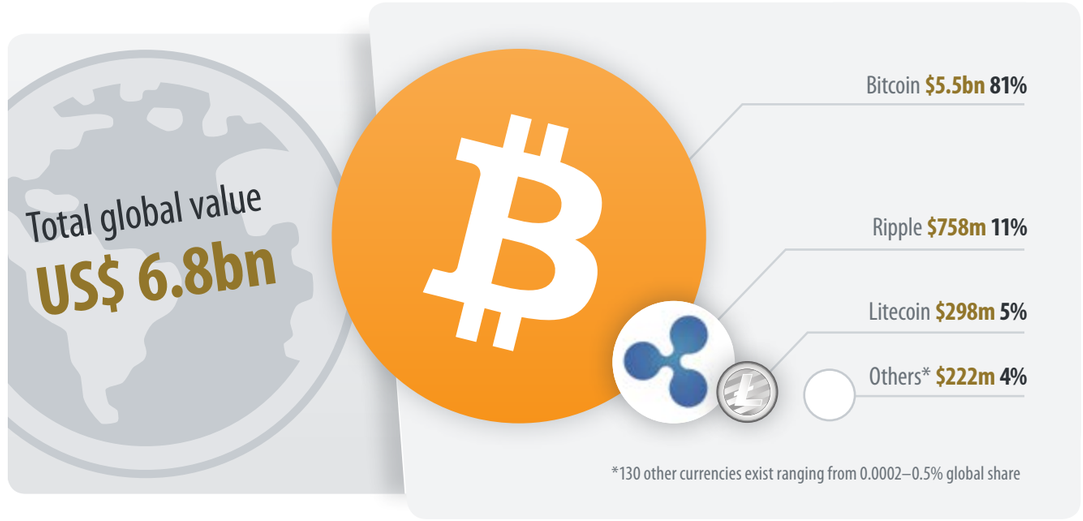
State-backed and alternative currencies

State-backed currencies will almost certainly still be the dominant form of money in 2045, although a global currency by then is improbable. A genuinely global currency would require a high level of international cooperation, likely to be brought about only in the case of an extraordinarily severe shock to the international financial system. Countries (or blocs of countries) are highly likely to remain the dominant seats of global authority by 2045. Consequently, such countries are likely to continue to be seen as the most reliable backers of monetary systems, above multinational corporations or private organisations. Further currency unions, such as the euro, are possible in the timeframe. State-backed currencies have an established position and usefulness that will almost certainly guarantee their persistence as the principal means of exchange. Advances in technology are likely to make online monetary systems increasingly important, but these will probably remain complementary to state-backed currencies, rather than replacing them.

"Non-state-backed currencies will continue to be used as a means of payment for online criminal activity."

Crypto currency values and market share

The crypto currency market is valued at over US$6.8 billion, with Bitcoin accounting for over 80% of the market.



Source: CoinMarket

There are, however, a number of situations in which alternative currencies could seem more attractive. For example, state-backed currencies could be undermined if government indebtedness rises sharply, perhaps due to an increase in interest rates. Similarly, if banking regulations become too onerous, alternative currencies may be more appealing to businesses and customers alike.

Even if these scenarios do not emerge, alternative currencies are likely to grow in size and importance out to 2045, constituting the main shift in the financial landscape. We are already seeing this trend. Although predominantly used for online transactions, Bitcoin has already been used to make offline purchases such as food and drink in pubs and restaurants.[4] If alternative currencies hold their value in the future better than those backed by the state, people may convert their savings into alternative currencies to insulate themselves from wider economic uncertainty. Currently, their volatility means that crypto-currencies are not considered a 'safe bet' for storing value. There may be an increase in international businesses carrying out transactions using online currencies to avoid exchange-rate volatility. Small businesses may increasingly turn to alternative currencies to avoid credit card fees and tax.[5]

States' monopoly on money is likely to be increasingly eroded by alternative currencies out to 2045. Alternative currencies may be able to bypass emergency capital controls or other measures taken by governments in the wake of financial crises. While this is only likely to have a limited effect on developed economies, there could be a greater impact on more economically closed countries (those nations which have a limited amount of external trade), which rely on capital controls to protect their national currencies. Governments' ability to raise revenue is also likely to be curtailed by the growth in alternative currencies. As ever-more transactions are carried out using alternative currencies, their anonymous nature is likely to provide a significant challenge to identifying and taxing economic activity.

However, alternative currencies are likely to remain vulnerable to attack. As with traditional forms of money, alternative currencies are only as secure as the organisation that controls them. Governments and commercial banks have technological advantages over ordinary users of their currency. They spend considerable resources securing their systems and responding to forgeries. By contrast, alternative currencies may come under attack from those who possess similar levels of skill and resources to the currencies' developers. For example, Bitcoin's infrastructure has been subject to several malicious attacks, with an attack in 2013 leading to its value dropping by 20%.[6] While there is no reason in principle why alternative currencies should not implement an improved security infrastructure, this would

"States' monopoly on money is likely to be increasingly eroded by alternative currencies out to 2045."

Alternative outcome:

Globalisation backlash

Globalisation could conceivably face a backlash, perhaps driven by anti-immigrant sentiment or resentment at perceived over-reaching of authority by international organisations. Although unlikely, there could be a corresponding rise in nationalism and economic protectionism, along with a reduction in international cooperation. In turn, this could lead to more conflict, particularly over water resources, energy and food. If institutions such as the European Union failed, there could be dramatic shifts in the global economy. Countries may be unable to effectively 'police' regions of the world on their own, leading to more failed states. Resurgence of national identity could encourage societies to become less proactive in tackling global issues such as climate change and poverty.

4 Shubber, K. (2013), 'London's Bitcoin Pub', available at http://www.wired.co.uk/news/archive/2013-06/17/london-bitcoin-pub

5 Needleman, S. (2013), 'More Small Businesses Embrace Bitcoin'

6 Clinch, M. (2013), 'Bitcoin Hacked: Price Stumbles After Buying Frenzy', available at http://www.cnbc.com/id/100615508

The requirement to hold US currency reserves may reduce

probably take time to develop and incur significant costs, which may be beyond the resources of most private organisations.

Reserve currencies

The US dollar is likely to remain the most important currency by 2045, but its status as the pre-eminent reserve currency will probably be eroded. Perhaps the most significant factor contributing to this eroding effect is the probable broad shift in economic power from West to East, meaning that the US is likely to account for a comparatively smaller part of the global economy. This trend is already evident, with the World Bank suggesting that the US accounted for 39% of global economic output in 1960, but only 22% in 2012. If this trend continues, the dollar is likely to become less central to global trade. As foreign reserves are used to make purchases and settle debt obligations, governments tend to hold the currencies of their major trading partners. Less trade with the US (as a proportion of global trade) may mean that there is less need for countries to hold US dollars as a reserve. The consequences for the US of a less dominant dollar could be significant. The US benefits from the dollar's reserve status to maintain its debt and to fund its expenditure. If the dollar becomes a less dominant reserve currency, it is likely that that the US will have to curb its expenditure. It is difficult to assess the implications of reduced spending but, as defence constituted 19% of federal expenditure in 2013,[7] it is likely that the defence budget will decrease. This may in turn limit the US's international military role and possibly influence.

China is likely to be the US's main rival as the global reserve currency provider within the 2045 timeframe. The recent growth of China's economy has not yet been mirrored by a growth in the prominence of its currency, the Renminbi. China's strict capital controls – designed to keep the value of the Renminbi low – have so far

"The dollar is likely to become less central to global trade."

7 Center on Budget and Policy Priorities (2014), 'Policy Basics: Where do Our Federal Tax Dollars Go?', available at http://www.cbpp.org/cms/index.cfm?fa=view&id=1258

prohibited developing international trade in the currency.[8] However, out to 2045, China is likely to want to grow its economy (and influence) still further by implementing significant financial liberalisation. As China develops and domestic demand grows, it is likely to make sense to allow the Renminbi to appreciate, allowing cheaper imports to satisfy a growing consumer class. Increasingly liberal financial measures could also allow the global market to deliver the kind of credit needed for a complex modern economy. China has already made some moves in this direction. It has encouraged an offshore Renminbi market in Hong Kong and allowed offshore banks to trade Renminbi among themselves, paving the way for Renminbi-denominated financial products. Perhaps most significantly, in September 2013, China's Central Bank announced that it wanted to accelerate loosening capital controls.[9]

The Renminbi is unlikely to replace the US dollar as the pre-eminent reserve currency in the 2045 timeframe, but it may become a rival to it. Currently, only a tiny minority of international foreign reserves are in the Renminbi. Although it is held by close trading partners such as Taiwan, most governments do not yet include it as part of their reserves.[10] However, it is likely that the Renminbi's rise as an international reserve currency will be preceded by its adoption as a major regional currency, and there is evidence that this is already happening.[11] For Chinese businesses, Renminbi internationalisation may offer a relative benefit in dealings with foreign firms, as trade can be carried out in their domestic currency. It also transfers exchange rate risk from Chinese companies to their foreign counterparts. These are factors which have long benefited US businesses, and may serve to increase China's overall competitive advantage.

"The Renminbi is unlikely to replace the US dollar as the pre-eminent reserve currency but it may become a rival to it."

8 Chey, H. (2013), 'Can the Renminbi Rise as a Global Currency? The Political Economy of Currency Internationalization'

9 Orlik, T. (2013), 'China Signals Speedier Moves to Loosen Capital Controls', available at http://online.wsj.com/article/SB10001424127887323623304579056741795219748.html

10 IMF (2012), 'Will the Renminbi Rule?', available at http://www.imf.org/external/pubs/ft/fandd/2012/03/prasad.htm

11 Peterson Institute for International Economics (2013), 'The Renminbi Bloc Is Here: Asia Down, Rest of the World to Go?'

Shock:
Global financial collapse

Following the drop in price of its principal exports, a massive uprising followed by a coup could fragment a large, pivotal economic power. Before its disintegration, such a country would almost certainly have held trillions of US dollars of foreign debt and would have been home to many of the world's most influential banks and investment companies. The collapse of this type of country could mean that global capital flows would be brought to a near-halt and the world's financial system would, in such a situation, cease to function effectively. Multiple defaults on payments could lead to the further collapse of numerous countries and potentially a collapse of the international trading system. If this occurred, hyper-inflation could take hold, making global trade drop to its lowest recorded level, with catastrophic consequences for the global economy.

Globalisation and financial shocks

Increased globalisation is highly likely to make transmission of financial shocks more widespread. The world will almost certainly become even more financially interconnected, with most western governments and multilateral financial institutions increasingly promoting the removal of restrictions on the flow of capital. While the 2008 financial crisis led to reduced international capital flows, money still moves relatively freely. One of the key benefits of the flow of money is that capital is allocated more smoothly throughout the world – investors are not limited to putting money into projects in their own countries. In turn, this helps smooth out economic imbalances and fosters higher growth.[12] However, more interconnectedness may also mean that financial shocks in one area of the world economy can be quickly transmitted to other areas. Arguably, volatile global capital flows have contributed to financial crises, such as the bursting of the East Asian credit bubble in the late 1990s and the 2008 global financial crisis. In line with the trend over the last 30 years, global capital flows are likely to increase out to 2045. The effects of this trend are difficult to predict, but it is reasonable to assume that the risk will be similar to those experienced so far. Although leading to an overall increase in wealth, it is likely that increased capital flows will lead to volatility in some parts of the global economy.

12 Peterson, *op. cit.*

Defence and security implications

- In the majority of cases, corruption will almost certainly continue to be a destabilising factor. This will disproportionately affect the poor.
- As corruption continues to prevent some aid money from reaching its intended recipients, donor countries may increasingly use direct investment as an alternative.
- The expansion of alternative currencies may make it easier to transfer and retain funds anonymously and hence harder for governments to freeze criminals' assets or sanction rogue regimes. Criminal and terrorist groups may also find it easier to transfer funds between jurisdictions.
- Out to 2045, alternative (non-state backed) currencies are likely to grow, having some effect on governments' ability to raise revenues.
- The US dollar's status as the pre-eminent reserve currency may be eroded making it more difficult for the US to fund its debt. This may lead to cuts in the US's defence spending and limit its international role.

Identity and the role of the state

The state will almost inevitably be the dominant actor in international affairs in 2045. Private or semi-state owned companies and non-governmental organisations are likely to exert increasing influence, but are less likely to exercise state-like legal and decision-making powers. Individuals may define themselves less by their nationality, with growing migration and stronger links to virtual communities. Rising costs, demands, technical complexity and need for specialisation could see private and other non-state entities increasingly functioning as the primary providers of those services that states have traditionally delivered, such as security. Some states may lose their monopoly on force, as private security contractors are increasingly employed and as some private companies take more responsibility for their own security. The extent to which these changes happen under the control of state-based decision-makers is likely to vary between countries according to their stability and forms of governance.

Personal privacy will very probably be increasingly difficult to achieve in the years leading up to 2045, as identity is ever-more defined by online activities. People are likely to demand higher levels of privacy protection from governments and businesses. Religion will probably remain a significant component of identity, with the spread of representative governments providing the space for some religions to become increasingly politically assertive. A range of technological enhancements have the potential to transform human identity by improving sensory perception, physical performance and perhaps even giving us the ability to control fear and other emotional states.

Governance

Since 1941 (when only 11 countries were democratic),[1] democracy, as a system of government, has spread. By 2012, the number of electoral democracies had reached 118[2] – just over 60% of all countries. Despite this, the spread of democracy has arguably slowed since 2000. In most established democracies, voter turn-out is reducing and could conceivably reach the point where the legitimacy of democratic institutions is challenged. Membership of political parties has also been reducing, as has trust in government. The 'Beijing Consensus' (a limited free market, with strong central control) is sometimes cited as an alternative to the Western democratic model. China's success at rapidly improving the standard of living of its population could be seen as proof that its system of governance is more effective (although democratic Brazil has achieved, proportionally, a similarly impressive feat). However, China's per-capita income is still substantially lower than that of established democracies, and looks likely to remain so by 2045.

1 The Economist (2014), 'What's Gone Wrong with Democracy?', available at http://www.economist.com/news/essays/21596796-democracy-was-most-successful-political-idea-20th-century-why-has-it-run-trouble-and-what-can-be-do

2 Freedom House (2013), 'Freedom in the World 2013', available at http://www.freedomhouse.org/report/freedom-world/freedom-world-2013

Although difficult to measure, the spread of information and ideas appears, on balance, to be increasing the pressure for governments to be accountable and representative. The increasing spread of information and communication technology (including Internet uptake) looks likely to accelerate this trend – and will probably lead to democracy continuing to spread out to 2045.

Interdependence and international organisations

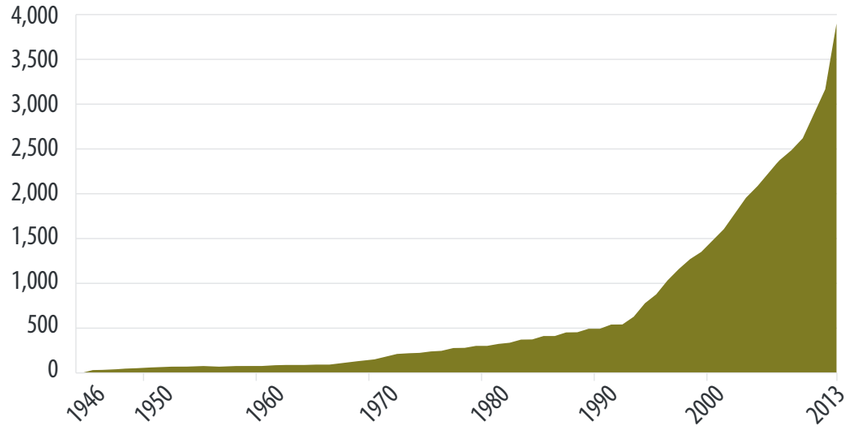
Globalisation is likely to lead to increasing constraints on countries' freedom of action, with countries likely to become more economically and politically interdependent. As economic power shifts from west to east over the next 30 years, international relationships and institutions are likely to undergo a similar change in power distribution. As well as becoming increasingly reliant on other countries for critical supplies of food, water, energy and materials, smaller countries, in particular, may find that the way to be most effective on the global stage is to work within blocs. Such blocs may be structured around regional alliances or shared values, to meet common interests in a more crowded environment. Current trends suggest we are likely to see more blocs with increased powers, although it is unlikely many will have the same level of authority as the current EU. Groups are also likely to be established to seek solutions for wider challenges, such as enabling trade or countering the effects of climate change and resource allocation. Future organisations may look similar to the G-20. Formed in 2008 as an emergency response to the global financial crisis, the G-20 has come to be recognised as the principal forum for leading states to agree global financial governance. Another example is the Alliance of Small Island States (AOSIS) whose member states are geographically dispersed, formed around the shared interest of highlighting and seeking solutions to rising sea levels. Through new groups like these, countries could challenge or seek to reform existing international organisations to provide legitimacy for their actions and increase their representation.

Such organisations may strengthen the conditions for countries to fragment. If sub-national regions believe that their interests will be represented by international organisations, they may have less reason to stay within their original country. This is not a new trend – regions within countries have split throughout history, and this trend is likely to continue out to 2045. As parts of supra-national organisations, countries are more likely to be subject to international rules, standards and institutions, further constraining their freedom of action. Increasing use of: international tribunals (such as the WTO Dispute Settlement Mechanism); transnational private arbitration arrangements; regional mechanisms (such as the European, African and American Courts of Human Rights); the EU arrest warrant; and the International Criminal Court, could bring formal justice systems closer together. Some of these organisations, though, have faced criticism which may hamper their future effectiveness – the International Criminal Court is sometimes accused of being overly focussed on Africa, with all six of its current cases from that continent. By 2045, there are still likely to be clear regional differences in legal and judicial practice even between close allies, such as the US and European countries.

Over the next 30 years, there is likely to be significant pressure on perhaps the most significant international organisation – the UN Security Council (UNSC) – to reform. Driven by the growing self-confidence of member states and the increasing economic strength of emerging countries such as India, Brazil, Nigeria and South Africa, there may be continued pressure to expand Council membership, which still does not include any permanent regional representation from Latin America, Africa or Oceania, and to reform its working practices to incorporate greater transparency. Such reforms may also be associated with an increase in the number of non-permanent members. Non-UNSC states' current lack of consensus as to what UNSC reform should look like, and unwillingness to expend effort pushing for change may, by 2045, be overcome by an increasingly evident disconnect between the international distribution of economic and military power and the distribution of political power in the UNSC.

Non-governmental organisations in consultative status with the UN Economic and Social Council

As of 2013 there were 3,900 organisations with consultative status: 147 in general consultative status; 2,774 in special consultative status; and 979 on the Roster. The status of 157 organisations is currently suspended.*



*There are 408 organisations with consultative status with other United Nations bodies or the specialized agencies for which entry dates are not recorded that are included under 2013.

Source: UN Economic and Social Council (2013)

Non-state actors

The concept of the state will almost certainly continue to exist by 2045 and states are still likely to have the most important voices in international affairs. Large private, or semi-private, companies and non-governmental organisations will very probably grow in number and power, seeking to influence national and international decisions.[3] Some multinational corporations are already worth as much financially as some national economies, with 12 multinational corporations among the top 100 economies.[4] For example, Apple is bigger, economically, than Ecuador, while Ford is bigger than Morocco.[5] Shell has a private security force of 1,200 people in Nigeria alone. Non-governmental organisations, such as major charities, also have significant voices and exert influence, entering into formal and informal negotiations with states.

3 Ritzer, G. (2010), 'Globalization: A Basic Text'

4 Lagarde, C. (2014), 'A New Multilateralism for the 21st Century: The Richard Dimbleby Lecture'

5 Risk Assessment and Horizon Scanning Programme Office, Singapore (2013), 'Future Stake'

At some major international conferences, the number of non-governmental organisations exceeds the number of states.[6] More than 3,500 non-governmental organisations have 'consultative status' with the UN Economic and Social Council,[7] up from 700 non-governmental organisations 20 years ago.[8] As a result of this growing influence, the next 30 years may see increasing calls for the largest multinational corporations and non-governmental organisations to have voices in, and be accountable to, supra-national organisations (such as the G77). Without such an accommodation, existing companies and non-governmental organisations may

6 For example, at the annual UN Framework Conference on Climate Change. The best-known of these conferences was held at Kyoto in 1997, when the Kyoto Protocol seeking to limit carbon emissions was signed.

7 Willets, P. (2013), 'The Growth in the Number of NGOs in Consultative Status with the Economic and Social Council of the United Nations', available at http://www.staff.city.ac.uk/p.willetts/NGOS/NGO-GRPH.HTM

8 Lagarde, *op. cit.*

> *"Non-governmental organisations, such as major charities, also have significant voices and exert influence."*

proliferate and become an increasing focus of policy-making, coordination and public lobbying and scrutiny to the detriment of state-based international organisations.

Private companies are also likely to provide many of the security functions currently provided by the state, with states increasingly contracting out their monopoly on force. Private companies already provide security in prisons and contribute to military operations – a recent Congressional report put the proportion of American contractors in Afghanistan, Iraq and the Balkans at more than 50% of the total number of US personnel present.[9] If this trend continues, by 2045, armed forces may have evolved into a confederation of public and private sector capabilities. Questions about regulation will almost certainly be raised if binding national and international legislation continues to apply to armed forces personnel, but not to private military contractors.

These patterns of non-state encroachment into areas where the state currently dominates are likely to take different forms in different countries. In robust, stable democracies and authoritarian states, state-based governing elites are likely to retain strategic direction and control, with the non-state sector delivering services and fulfilling functions rather than exercising power. Increasing interchanges between governing and commercial elites (for example, as traditional career structures break down) may blur the boundaries of state and non-state influence and policy-making, particularly in states with weaker systems of transparency and control. Some fragile, unstable, resource-dependent states may well find themselves subject to greater pressures, particularly from transnational enterprises wholly or partly owned by other states.

"The state will probably be of less relevance to the individual, due to the movement of people, information and ideas across national boundaries."

National identity

By 2045, more individuals are likely to define themselves less by their country of origin or residence than they do today. In developing countries, some people may continue to feel more closely bound by tribal allegiances or other loyalties than connected to the state. Globally, the state will probably be of less relevance to the individual, due to the movement of people, information and ideas across national boundaries. As individuals feel less connected to the state, they are also likely to become less interested in supporting it.[10] (This is far less likely to be the case in autocratic regimes, where nationalism may increase.) Participation in politics in mature democracies looks likely to continue to fall, which could result in citizens challenging the legitimacy of their governments. Finally, as global connectedness (particularly economic interdependence) grows, people may move abroad more frequently. We are already seeing this trend with UN figures showing that in 2013, the number of international migrants worldwide reached 232 million, up from 175 million in 2000 and 154 million in 1990.[11]

State provision of services

A growing population may undermine some countries' ability to provide services, causing unrest. As expanding and aging populations grow more demanding of ever more personalised, technologically advanced medical, financial and other services, and as supply chains grow more complex requiring more specialisation and more sophisticated project management techniques, states may need to turn increasingly to the private and non-governmental sector to deliver essential services. While developed countries are likely to be able to have the resources to meet these demands – or at least are likely to be able to import or contract out the means to respond to them – this is less likely to be the case for some developing countries. If countries are unable to provide vital services required by their growing populations, their citizens are likely to become increasingly discontent, which may manifest itself in protest or unrest. Protest is likely to be facilitated by advances in communications technology, allowing those who are discontent with their government to challenge it collaboratively, as seen in the 'Arab Spring'.[12] This could lead to increased civil unrest and in extreme cases a disintegration of order in affected countries.

A key service that the state is less likely to be able to provide in future is security, particularly information security. As people live more of their lives online, safeguarding personal data is likely to be increasingly important. Private companies already provide much of our communications infrastructure, from delivering post to providing phone and email services, and it seems likely that – in response to customer demands – they will take greater responsibility for making sure those services are secure. Similarly, despite reducing rates of crime, individuals may be more likely to seek alternatives to the state to provide their physical security.

Digital anonymity will be increasingly difficult to maintain

Privacy

The longevity of data storage means that there is an ever-growing record of people's activity, and attempts to avoid leaving a digital footprint may become increasingly difficult. At the same time, the growth in the number of surveillance devices is increasing at a rapid rate and, unless individuals go to great lengths to avoid detection, it is likely that by 2045, a near-complete record of their movements could be built up by an interested party. Much of the data created and rendered accessible by the information age has the potential to benefit society. For example, criminality may prove increasingly difficult to conceal, allowing governments, businesses and individuals to be held to account. But governments may also increasingly exploit extensive databases and surveillance devices to monitor and curtail individuals' activities.[13] It is, however, likely that individuals and societies will demand higher levels of privacy protection from their governments and from businesses that they interact with. Public demand for encryption software could increase as individuals seek to live their digital lives without leaving a permanent trace. However, it is likely that governments will resist such demands as their ability to detect and prosecute criminal activity could be impeded.

Religion and ideology

Religion is likely to remain a significant component of people's identity, with evangelical Christianity growing in popularity in Latin America, Asia and Africa, as well as Islam becoming more prevalent in the Middle East and North Africa.[14] Some religions are likely to become increasingly politically assertive.[15] This influence will almost certainly continue to be assisted by globalisation and by developments in communications technology, permitting the messages of religious groups to unite diaspora populations and appeal to a far wider audience than previously possible. Technology is also likely to contribute to diaspora communities being increasingly affected by intra-faith discord in countries of origin. Some governments

9 Congressional Research Service (2013), 'Department of Defense's Use of Contractors to Support Military Operations: Background, Analysis, and Issues for Congress'

10 Cooper, R. (2004), 'The Breaking of Nations'

11 UN (2013), '232 Million International Migrants Living Abroad Worldwide – New UN Global Migration Statistics Reveal', available at http://esa.un.org/unmigration/wallchart2013.htm

12 RAND Europe (2013), 'Thinkpiece for a 'Future Role of the State' Workshop in Support of the GST Programme'; High Level Panel on Fragile States (2014), 'Ending Conflict and Building Peace in Africa: A Call to Action'

13 Schmidt, E. and Cohen, J. (2013), 'The New Digital Age'

14 Micklethwait, J. and Wooldridge, A. (2009), 'God is Back'

15 *Ibid.*

may have to address new challenges from religious groups. For example, by 2045, China may be home to some of the world's largest Muslim and Christian populations and its internal politics and global posture are likely to be influenced significantly by the manner in which these two faith groups pursue their goals and seek religious freedom.[16] As religion is so fundamental to many people's identity, where tensions between different groups exist, they are likely to be exacerbated by religious differences.

While there is little evidence to suggest that ideologies as influential as communism and fascism were in the 1930s and 1940s are emerging, ideology is likely to remain an important component of many people's identity. The desire by some to make all information freely available is, possibly, an example of an emerging ideology.

Shock:
Sectarian conflict

Areas of considerable sectarian tension exist across the world – if there was a prolonged period of escalation, campaigns of terrorist attacks could be carried out on a previously unseen scale. It is possible that attacks on such a level could cause a major power to descend into civil war. Pre-existing religious divides could rapidly escalate into a transnational conflict between two aspects of the global society. It is possible that some countries would be drawn into a wider war, as pressure from their populations, existing treaty obligations and allegiances force them to take sides. If the UN was deadlocked, unable to manage this degree of polarisation, widespread killings could occur across the globe.

16 Micklethwait and Wooldridge, *op. cit.*

China will be home to one of the world's largest Christian and Muslim populations

Human augmentation

Future technologies may make it possible for people to radically alter their identities by using a range of physical and cognitive enhancements. The power and range of the five major senses is likely to be significantly enhanced, often as a result of extending and applying developments made for medical reasons. Some developments are likely to require surgical implants, implying a degree of permanence – others will probably be temporary. However, it is difficult to speculate on the extent to which enhancing sensory perception will lead to improved interpretation of our surroundings. Some augmentations could provide signals from beyond our normal sensory range. Despite its inherent adaptability, it is not clear how well the human brain will be able to process such data to produce useful information and analysis.

New technologies may be able to extend our visual sense beyond the range of visible light into other parts of the spectrum. Implants designed to help restore sight provide an early indication of what could be achieved in allowing us to 'see' otherwise non-visible radiation.[17] Our hearing could be significantly enhanced. Hearing aids are currently being developed that can choose and boost frequencies of interest which would enhance the ability to detect and understand speech in noisy environments.[18] Similarly, improved understanding of how the brain can discriminate between individual smells in a mix of odours found in a typical room[19] could provide the basis for developing future technology that may enhance our sense of smell. Even the tongue could be used as a novel pathway to conduct a range of sensory information to the brain, from external sensors such as cameras or sonar.[20]

Advances in a range of disciplines, such as brain science and pharmacology, are likely to increase our ability to influence emotional responses such as motivation, anxiety and fear – all of these affect individual performance in areas of considerable significance. Cognitive function may be enhanced either by machine interfaces or by using chemicals. Treatments, often developed to address mental health issues, may be widely used by healthy people to augment or optimise cognitive performance, offering potential enhancement of many aspects of cognition, from learning and memory to wakefulness, attention and motivation.[21]

External and internal electro-mechanical devices are likely to enhance human physical performance. For example, powered exoskeletons already in development allow users to lift loads of up to 90kg without their performance being impaired, as well as reducing fatigue experienced when exercising.[22] Prostheses are being developed that exceed the functionality of the limbs they replace and whose electronic control systems outperform the original. Brain-machine interfaces may allow direct control of prostheses, exoskeletons and systems remote from the body. Control of simple devices by thought is already a reality.[23]

Some social and religious groups may not wish to adopt these new augmentations for ethical

"External and internal electro-mechanical devices are likely to enhance human physical performance."

17 For example, see Planker, D. (undated), 'Restoration of Sight to the Blind: Optoelectronic Retinal Prosthesis', available at http://www.stanford.edu/~palanker/lab/retinalpros.html

18 For example, see ABC Science (2008), 'Chinese Frog has Tuneable Ears', available at http://www.abc.net.au/science/articles/2008/07/29/2317848.htm

19 For example, see Phys.org (2007), 'Neuronal Circuits Able to Rewire on the Fly to Sharpen Senses', available at http://phys.org/news117036872.html

20 For example, see University of Nebraska (undated), 'Train the Brain', available at http://www.unmc.edu/mmi/docs/TrainTheBrain.pdf

21 Office of Science and Technology (2005), 'Drugs Futures 2025', available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/299221/05-1182-drugs-futures-overview.pdf

22 Berkeley Robotics & Human Engineering Laboratory (undated), 'Research Projects – HULC', available at http://bleex.me.berkeley.edu/research/exoskeleton/hulc/

23 Goudarzi, S. (2006), 'Human Thoughts Control New Robot', available at http://www.livescience.com/9446-human-thoughts-control-robot.html

reasons, in much the same way that the Amish communities of Northern America currently reject most modern technology. Equally, not all who wish to adopt these new technologies may be able to do so – the rich will almost inevitably have better access than the poor. Many of the technologies described above will almost certainly be expensive (at least initially), leading to the prospect of poorer people being excluded from the benefits that technological enhancements may provide. Such inequality could lead to disaffection and instability when such groups perceive themselves as being marginalised. Conversely, it is plausible that in the longer term, improved and mass-produced technologies may provide for greater equality in delivering healthcare.

"It is possible that direct brain-to-brain communication may be achieved by 2045, transforming ways of working."

Direct interfacing

It is possible that direct brain-to-brain communication may be achieved by 2045, transforming ways of working. The real-time transfer of behaviourally meaningful information between the brains of two rats has already been demonstrated, with rats successfully performing tasks that they had not previously attempted.[24] Building on the progress that has been made with animals, the ability to move another's hand through non-invasive brain-to-brain interfaces has already been demonstrated.[25] If extended to complex cognitive tasks, the approach of directly linking brains could be the basis for wholly new methods of decision-making, problem solving and planning. These methods could involve collaboration and using directly-shared knowledge and experience between humans (and potentially between humans and other species).

As well as potentially transforming both sensing and decision-making, direct brain linkage could have profound implications for social interaction and for the notion of what it means to be an individual human being. As seen with current interaction with virtual environments, where high-use levels sometimes lead to addiction,[26] there could be powerful behavioural effects. Notions of individuality could be challenged, possibly leading to questioning of loyalties and allegiances to organisations, as individual and group identities merge. By 2045, it is even possible (although unlikely) that the sharp distinctions between people and machine will disappear.

24 Pais-Vieira, M. *et al.* (2013), 'A Brain-to-Brain Interface for Real-Time Sharing of Sensorimotor Information', available at http://www.nature.com/srep/2013/130228/srep01319/full/srep01319.html

25 Armstrong, D. and Ma, M. (2013), 'Researcher Controls Colleague's Motions in 1st Human Brain-to-Brain Interface', available at http://www.washington.edu/news/2013/08/27/researcher-controls-colleagues-motions-in-1st-human-brain-to-brain-interface/

26 American Psychiatric Association (2013), 'Internet Gaming Disorder Fact Sheet', available at http://www.dsm5.org/Documents/Internet%20Gaming%20Disorder%20Fact%20Sheet.pdf

Identity and the role of the state

Defence and security implications

- The pressures of globalisation are likely to mean that individual countries will find it increasingly difficult to act unilaterally – most countries are likely to be less powerful. This could reduce conflict.
- The state is still likely to have the most important voice in international affairs, but out to 2045 the private sector and non-state organisations are likely to grow more influential. There is likely to be an increase in the use of private security companies by governments – interdependencies may strengthen, despite their largely separate motivations.
- Non-state actors, such as multinational corporations, are likely to grow in influence and some may develop highly capable security forces. The private sector and non-governmental organisations are likely to increase their influence over government policy-making as developed states rely on them for providing services and as they gain greater control over markets, resources and infrastructure in fragile states.
- Advances in communications technology may increasingly enable those who are discontent with local forms of governance to challenge it, in pursuit of perceived betterment.
- Some augmentation of humans with embedded sensors and computing devices is likely to occur within the 2045 timeframe. This may provide advantages such as improved situational awareness, health monitoring and the ability to modify physiological and psychological states to increase performance and enhance resilience.
- Mind-controlled machinery is likely to become much more sophisticated, with human brain-to-brain communication possible by 2045.

Global Strategic Trends

Defence spending and capabilities

Chinese defence expenditure is likely to rival that of the US over the next 30 years, reflecting China's growing economic strength. These two global powers are likely to spend far more on defence than any other country, accounting for almost half of the world's total defence spending by 2045. India's defence budget could see it occupying a 'second tier' by 2045. Russia is likely to increase defence spending, although not quickly enough to match that of China, the US or India. European countries are likely to continue to spend substantial amounts on their armed forces, although their spending is unlikely to increase significantly unless a major threat emerges. Advances in technology are likely to lead to increasingly effective non-lethal capabilities and increase the precision of weapons. This is likely to alter the nature of conflict.

Economic growth

Defence expenditure, at least in peacetime, has historically depended on a country's economic strength. By 2045, the world's largest economies (by GDP) are likely to be China and the US, with India likely to be the only country in a 'second tier'. Some experts suggest that the US and China may account for 45% of global defence spending in 30 years' time.[1] Although the EU as a whole is likely to have a GDP comparable to the US (although smaller than China) and spend a similar amount to India on defence, no single European country is likely to have a defence budget comparable to these three powers.[2] Additionally, China, India and the US are likely to lead in defence-related research and development – further enhancing their military capabilities. Russia is likely to increase defence spending, although its economy is unlikely to grow quickly enough to allow it to match the future defence spending of China, the US or India, even if its expenditure as a percentage of GDP were to rise. Those countries currently occupying the 'second tier' of defence spending (such as France, Germany and the UK) are likely to continue to spend substantial amounts on their armed forces, broadly maintaining their positions relative to each other, but are unlikely to increase their defence spending significantly unless a major threat emerges.

Political impacts of changing defence spending

At the moment, those countries with the largest defence budgets are also permanent members of the UN Security Council. As levels of defence spending change, it is possible that pressure will increase for membership reform. If some permanent members spend less on defence, they are likely to be less able to contribute to military operations, relying more heavily on support from others. In turn, this could affect their political power and influence. As the cost of staying ahead in a global technology race seems likely to increase, maintaining a technological advantage could increasingly be achieved by cooperation and burden-sharing. Of course, higher defence expenditure does not necessarily lead to greater military influence. For example, although India is likely to spend more on defence than the UK, it will almost certainly have to overcome domestic political

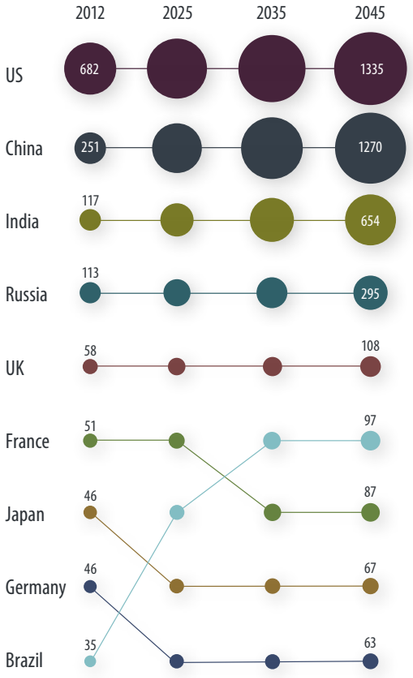
1 Internal MOD economic analysis (2014)

2 *Ibid.*

issues and improve the way it invests to attain the capabilities needed to project conventional military power globally. While spending on defence is usually highest during conflict, deterrence can also be associated with high levels of spending – for example during the Cold War.

Defence expenditure

Expenditure (adjusted for ***purchasing power parity***)*, expressed in US$ billion at 2012 values.



Based on analysis by MOD economics unit 2014.

*Purchasing power parity expresses a country's expenditure in the equivalent US$ that would be required to purchase the same amount of goods and services in the US domestic market.

Equipment and personnel cost inflation

Unlike civilian technology, there is no trend that suggests military equipment will become cheaper as technology advances. The latest platforms are more expensive in real terms than previous generations. If this trend continues, armed forces are likely to have smaller quantities of extremely expensive equipment, suggesting that by 2045 only the two highest-spending nations – the US and China – would be able to afford a large and cutting-edge air force and navy. Whilst countries account for their Service personnel costs in differing ways – making comparison difficult – it seems likely that the Service personnel costs per capita of many countries (including China) are increasing at a faster rate than inflation – this may act as a spur for automation.

Future weapons

Increased levels of defence spending and continuing advances in technology are likely to lead to a variety of new weapons being available by 2045. For example, laser systems are maturing, with vehicle and sea-based platforms already at advanced stages of trial.[3] Directed energy weapons, such as lasers, could be capable of discrete target discrimination, producing a focussed beam (or wider field) of electromagnetic energy or atomic radiation to cause disruptive or damaging effects to equipment and infrastructure. Such weapons may also be capable of delivering non-lethal effect on human targets at considerable distances. Increases in the number and sophistication of sensors (civil and military) are likely to increase the accuracy of targeting, as well as making it increasingly difficult to hide people, machines or equipment. As people use electronic devices more frequently, the ability to target an individual by their 'digital signature' is likely to become easier. Similarly, as the cost of sequencing an individual's DNA continues to fall, targeting an individual using their DNA may be possible by 2045. We could also see sophisticated environmental warfare, capable of spreading plant and human diseases by insects or insect-machine hybrids. Crops and cattle could be destroyed, as well as people being incapacitated or killed.

Globalisation, in particular the spread of technology, information and ideas, is likely to give an increasing number of people (both state and non-state actors) access to sophisticated and technologically advanced capabilities. This is likely to increase the opportunity for unconventional attacks on technologically sophisticated nations, including by terrorists. However, future technology may also be developed to predict, detect and counter such attacks.

3 BBC (2013), 'Rheinmetall Demos Laser that can Shoot Down Drones', available at http://www.bbc.co.uk/news/technology-20944726; Greenemeier, L. (2010), 'U.S. Navy Laser Weapon Shoots Down Drones in Test', available at http://www.scientificamerican.com/article.cfm?id=laser-downs-uavs. For announced deployment see USNI News (2013), 'Navy to Deploy Anti-UAV, Small Boat Laser Next Year to Gulf', available at http://news.usni.org/2013/04/08/navy-to-deploy-anti-uav-small-boat-laser-next-year-to-gulf

The US/Israeli THEL system has spurred development of more capable laser weapons

Shock:
Weaponised virus

Technological advances could allow a rogue regime, terrorists or criminal groups to synthesize highly contagious, fatal viruses with long incubation periods that would make early detection and quarantine very difficult. The promise of an anti-virus could be used to extort money, goods or used for political leverage. It is even possible that viruses could, in future, be engineered to target specific individuals or groups, making them a more viable weapon.

Levels of conflict

Although many people see the 20th and early 21st centuries as being the most violent and bloody in human history, evidence suggests that the frequency and intensity of wars, as well as the number of violent deaths, has been declining sharply and is likely to continue to fall.[4] For example, no western European countries have gone to war against each other since the end of World War II, but by contrast, in the 600 years before 1945, they started an average of two new wars each year. Although the number of civil wars increased after 1945, these have also been on the decline since 1991. Countries are also much more willing, globally, to get involved in peacekeeping, with peace-support operations dramatically increasing since the end of World War II (although they have slightly decreased in number since 2000).[5] Of course, the risk of a major conflict will almost certainly remain. Historically, the rise of two or more great powers in close physical proximity is usually correlated with war or conflict – and there are a number of such potential flashpoints around the world, looking out to 2045.

Nature of conflict

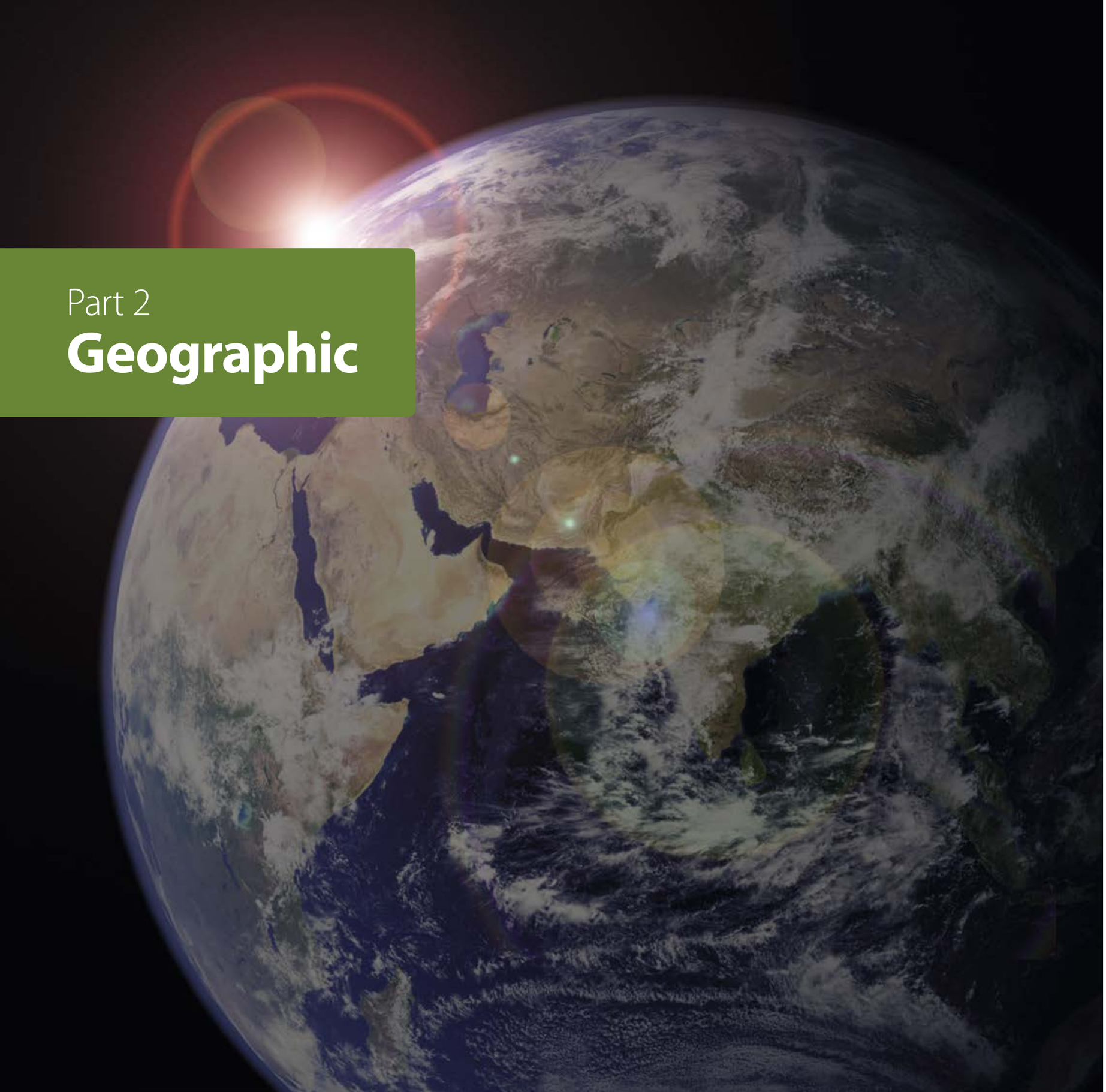
The nature of conflict will almost certainly continue to change, particularly as a result of technology. Increasing use of unmanned systems may mean that, in the future, physical conflict could occur between unmanned systems (for example, using remotely piloted aircraft to attack an unmanned oil installation). The opportunities for bloodless attacks could lower the threshold for conflict. Similarly, as people become more connected and dependent on technology, the potential for inflicting significant harm on an adversary without the need for violence, is likely to increase. Power distribution networks or banking systems could be closed down, rather than more physically destructive action being taken. Furthermore, globalisation is likely to provide opportunities for actors to create social and political instability. For example, the reach and penetration of the internet could be used to spread disinformation; social media could be used to incite specific interest groups and organisations; and the actor's diaspora communities could also be exploited, particularly where they have local grievances. When violence does occur, technology is likely to make applying it more precise, and possibly, more effective. For example, targeted assassinations of the family members of a ruling elite (or the threat of them) may have more of a deterrent effect than the threat of war. Nevertheless, war is ultimately a human endeavour. It will be humans who choose to go to war, it will be humans who can stop wars and it will be humans who suffer the consequences of war.

4 Pinker, S. (2011), 'A History of Violence: Edge Masterclass', available at http://edge.org/conversation/mc2011-history-violence-pinker

5 *Ibid*.

Defence and security implications

- The US and China are likely to have similarly sized defence budgets by 2045, potentially out-spending the rest of the world.
- India could have a defence budget equivalent to the EU's total spending on defence. This would put India in a 'second tier' of global defence expenditure, with a 'third tier' (comprising countries such as France, Germany, Russia and the UK).
- The link between expenditure and capability is not straightforward. Domestic political problems may undermine the effectiveness of some countries' armed forces. Other countries may choose not to develop global military reach.
- Increasing real-terms equipment costs indicate that platforms will become ever more expensive. Higher levels of defence spending may not lead to armed forces larger than today's.



Part 2

Geographic

Expanding on the observations made in Part 1, we consider regional and (where appropriate) country-specific effects of themes, trends and drivers.

1 Bermuda
2 Canada
3 Greenland
4 Saint Pierre and Miquelon
5 United States of America

Northern America

By 2045, Northern America's population is likely to grow to between around 394-478 million and become more ethnically diverse. Climate change is likely to open up shipping routes during the summer months, as well as new areas for extracting minerals and hydrocarbons in the Arctic. However, it is also likely to cause significant harm through heatwaves, droughts, and flooding across the region. Northern America's economic outlook is positive, boosted by newly accessible energy reserves, and it is expected to integrate ever more closely with the global economy. While security challenges (including the threat of terrorism) will probably endure, the region is likely to remain stable and politically influential. The India-US relationship has the potential to become significant in the timeframe, but the pre-eminent relationship for the region is likely to be between China and the US, particularly as trading partners. However, there will almost certainly remain a number of issues that could give rise to tensions between the two countries.

Demography

Driven principally by a mixture of immigration and a high birth rate in the US, the overall population of Northern America is likely to increase from 352 million today to between 394 to 478 million by 2045.[1] Canada's population is expected to grow to between 40 to 48 million, although this is likely to be due to immigration rather than the birth rate, as the latter is expected to reduce. Canada's population is likely to be increasingly ethnically diverse, but less so than that of the US. While Canada's population is likely to age, immigration and a changing economic emphasis towards production should help meet the demographic challenge. The US population is expected to have grown by about 80 million by 2045,[2] and will be more ethnically diverse. By 2045, the US is likely to have a strong working age population comfortably able to provide for its elderly. This is likely to differentiate the US from most other developed economies, playing a key role in ensuring that the country's economy continues to prosper. The social impact of these changing demographics is expected to be comparatively small due to the strong and inclusive nature of American culture and its continuing progress in managing diversity. Radical changes to US policy (especially foreign policy) as a result of its changing ethnic mix are, therefore, unlikely.

Urbanisation

The populations of the major cities are likely to grow significantly,[3] in line with global trends towards increased urbanisation. If regeneration programmes are prioritised, scores of new communities could be created following the redevelopment of rundown inner cities – although some urban areas may fail, contributing to security issues. New

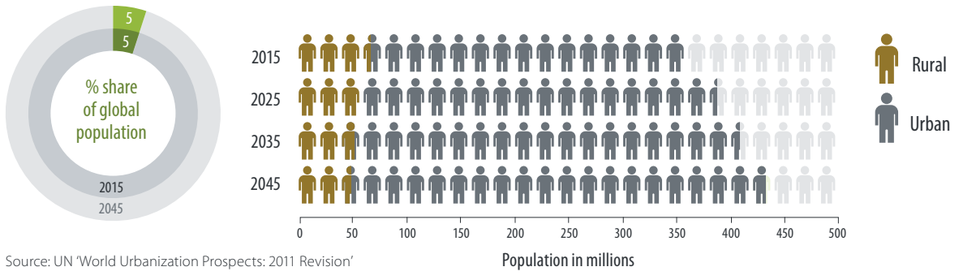
"The US is likely to have a strong working age population comfortably able to provide for its elderly."

1 UN (2012), 'World Population Prospects: The 2012 Revision', available at http://esa.un.org/wpp/unpp/panel_population.htm

2 *Ibid.*

3 Kotkin, J. (2010), 'America 2050: Where and How We'll Live', available at http://www.newgeography.com/content/001469-america-2050-where-and-how-well-live

A growing population living in the urban environment

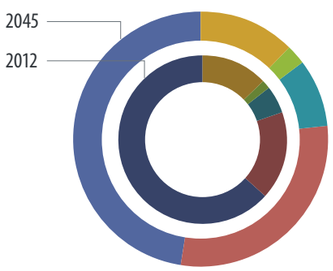


Source: UN 'World Urbanization Prospects: 2011 Revision'

towns are also likely to spring up around newly developed oil and gas fields. City-dwelling is likely to remain popular with the young and ambitious, but suburbia – the predominant form of America life – will probably evolve beyond the conventional 1950s-style 'production suburbs' of vast housing tracts constructed around existing commercial and industrial centres. Instead, they are likely to become more compact and self-sufficient, providing office space as well as accommodating an increasingly home-based workforce. One in four or five Northern Americans are likely to work from home by 2045 – and as remote working relies on frequent communication with others, potentially across the globe, this may break the traditional isolation of rural communities in the heartland of Northern America.[4]

US population by group

The charts show the change in population composition between today and 2045.



Source: US Census Bureau and UN Population Division

Education

The best-performing Northern American universities, particularly those in the US, are likely to remain globally competitive. This should benefit the region's economy and allow it to maintain technical dominance in a number of fields, although it is of note that many of the students enrolled on graduate and science and technology courses are born outside Northern America. Northern American universities are also at the forefront of digital learning, and may well retain leadership in this field – further benefiting the region's economy and academic standing. In the US the standard of primary and secondary education for some of the less affluent is comparatively low for a developed country, and on current trends is likely to remain so. This may mean that some elements of the labour force may not be able to achieve the educational standards that are likely to be needed in the information-driven economy of 2045. This could lead to high unemployment rates, further exacerbating inequality, which may lead to significant social tension. If, as seems likely, educational standards in other countries continue to rise, the US economy may start losing its competitiveness if no mitigating action is taken.[5]

4 Kotkin, J., *op. cit.*

5 Nye Jr., J. S. (2010), 'The Future of American Power', available at http://www.foreignaffairs.com/articles/66796/joseph-s-nye-jr/the-future-of-american-power

Climate change

Climate change is likely to have a mixed impact on Northern America, although the overall effect will probably be negative. Melting ice in the Arctic is likely to open up areas of land for extracting minerals and hydrocarbons, and access to new summer shipping routes, could have a beneficial impact on Northern America's economy. Melting permafrost in northern Canada and Alaska could, however, have large and costly implications for infrastructure that is built on top of it, such as pipelines or ice roads. Climate change will probably have a negative impact on the forest industry, extending the forest fire season and facilitating the spread of pests, such as the pine beetle.

The impact on agriculture from climate change is also likely to be mixed. Average annual rainfall is likely to increase in all regions except for the Canadian Prairies, the west coast, and south-west US. The Colorado River (a major freshwater source used for agriculture, water storage and energy generation), could see run-off reduced by around 10-30% by 2045, potentially leading to water shortages. The cost of water stress on agriculture throughout Northern America is expected to be in the billions of dollars by 2045. Severe heatwaves could hit Northern America, with some east coast cities (including Washington, New York and Toronto) likely to see an increase in their maximum summer temperatures. This could cause power failures, crop damage and high death-rates among vulnerable people such as the young and elderly. At the same time, moderate climate change could increase yields from rain-fed and irrigated agriculture in some parts of the US and Canada. The US produces more than 30% of the world's wheat, soybean, corn and rice. Some crop yields could increase with moderate changes in the climate (particularly in northern regions) but continuing warming may cause significant decreases. One study suggests that maize yield could decrease by as much as 18% by the 2040s.[6] Rising sea levels and intense rainfall could leave coastal cities and regions more exposed to flooding, particularly in the Mississippi delta and cities along the east coast such as New Orleans, Miami and New York.

Energy independence

If the recent adoption of new oil and shale gas production techniques such as 'fracking' continue to increase production at expected rates, the US could become the world's number one oil producer by 2017 and a net exporter by 2030. Exploiting and exporting unconventional oil and gas, however, is not without its challenges. If such problems can be overcome (as seems likely), the cost of energy could return to pre-1970s prices.[7] This would provide a significant advantage to the Canadian and US economies, which contain particularly energy-intensive industries. Consumers should also benefit through lower energy bills, leaving them more money for discretionary purchases; and because natural gas burns more cleanly than coal, there could be environmental benefits. Northern America is also likely to generate an increasing proportion of its energy from renewable resources, further strengthening its energy security. Energy independence is unlikely to mean that Northern America will become detached from global markets. On the contrary, the region is likely to export hydrocarbons internationally and – with Asia's demand for hydrocarbons expected to grow – the potential for mutually beneficial trade should increase. However, relationships with countries that used to export hydrocarbons to Northern America may cool as mutual dependence lessens.

"The US could become the world's number one oil producer by 2017 and a net exporter by 2030."

Economy

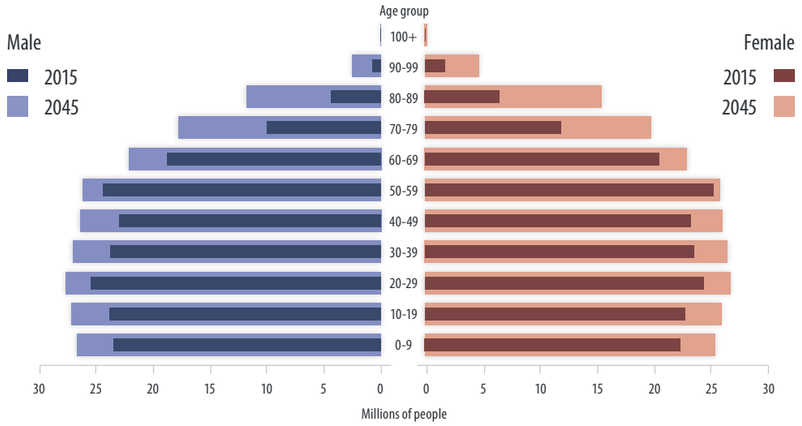
Despite the expected shift in the economic centre of gravity to the south and east, Northern America is expected to remain a major player in the world economy out to 2045. Its share of global GDP is likely to remain

6 Urban, D. *et al.* (2012), 'Projected Temperature Changes Indicate Significant Increase in Interannual Variability of U.S. Maize Yields', available at http://link.springer.com/article/10.1007%2Fs10584-012-0428-2

7 Christopher J. Wolfe, Chief Investment Officer of the Private Banking and Investment Group at Merrill Lynch, "We could end up with the cost of energy to U.S. manufacturers returning to what it was in the 1970s or even the '60s, adjusted for inflation." Quoted in Merrill Lynch (2013), 'A Transforming World', available at http://wealthmanagement.ml.com/publish/content/application/pdf/GWMOL/AR9D50CF-MLWM.pdf

An ageing population

Population by ten-year age group and sex



Source: UN (2012), 'World Population Prospects: The 2012 Revision'

about 20%, and the US will almost certainly remain the dominant player in the region with its 85% share of the regional economy unlikely to change significantly. While China's GDP is highly likely to have surpassed that of the US by 2045, on a per-capita basis the US will probably be five times richer. Furthermore, although the US is likely to face a variety of internal issues, these are likely to be less severe than domestic problems affecting China, if only because of the difference in the sheer numbers of people involved. This is likely to mean that the US will have greater uncommitted resources available than China (or any other country) – a position that is only likely to strengthen due to its newly-available energy reserves. However, despite this positive outlook, there are a number of risks to the US, such as the rising costs of healthcare and other welfare entitlements which could burden its economy by 2045. In particular, if its debt grows, the cost of servicing it could become increasingly onerous – and an increasing threat to the long-term health of the US economy.

"Northern America is expected to remain a major player in the world economy out to 2045."

The international system

Regional economic interdependence is expected to strengthen, and although the development of the North American Free Trade Agreement has been somewhat bumpy, the shared interests of its member countries (Canada, Mexico and the US) could make it one of the strongest regional economic blocs in the world.[8] Northern American countries are also likely to continue to deepen their integration with the international system. Both Canada and the US are likely to remain committed to the Trans-Pacific Partnership and they, along with Bermuda, Greenland and St Pierre and Miquelon are likely to be included in the Trans-Atlantic Free Trade and Investment Partnership. The region is likely to remain highly influential within the international system and the US is likely to remain at the forefront of world politics. By 2045, the US is still likely to have the most powerful military in the world and retain considerable political influence.

NATO is likely to remain the key security alliance for Northern American countries, although US (and possibly Canadian) commitments elsewhere in the world are likely to mean that European countries will have to assume more of the security burden in their region – and possibly in Africa and the Middle East as well. Nevertheless, the US will probably continue to invest in NATO and

8 Lanthemann, M. (2014), 'NAFTA and the Future of Canada, Mexico and the United States', available at http://www.stratfor.com/weekly/nafta-and-future-canada-mexico-and-united-states

The region is likely to remain highly influential within the international system

is likely to remain the guarantor of European stability. The US and Canada are also both likely to continue to be significant contributors to the UN and the US membership of the UN Permanent Security Council is highly likely to continue out to 2045. If the US became disengaged from the UN, it would be likely that the organisation's credibility and capacity would be severely damaged.

US commitment to the Middle East

A reduced need for Middle Eastern oil (coupled with a shift in the Middle Eastern markets toward Asia) could bring the US commitment to the Middle East into question. However, US involvement in the Middle East is unlikely to alter significantly, as the region will almost certainly continue to have a significant bearing on global stability and security. The US also has long standing commitments to countries in the region – not least Israel. Quite apart from political concerns, the oil market is genuinely global. The price of oil in the Middle East affects the price of oil produced in the US, meaning that any serious disruption in the former could have a knock-on effect on the global economy.

US rebalancing towards the Asia-Pacific region

With the growth in Asia's economic power, Canada and the US are likely to increase their focus on the region, as demonstrated when the US announced a rebalancing towards the Asia-Pacific area. Although both Canada and the US have strong ties to several countries in the region, the pre-eminent relationship is likely to be between China and the US – one which is likely to continue to be extremely complex. While the US has viewed the increase in Chinese military capability, particularly its lack of transparency, with concern, America's economy is tightly tied to China. China owns US$ 1.4 trillion of American debt (approximately eight percent)[9] and the mutual trade in goods is valued at US$ 502 billion annually.[10] Both figures could grow out to 2045. Such economic interdependence is likely to act as a stabilising influence and should reduce the likelihood of military conflict.

There are, however, a number of issues which may result in conflict between the two powers. US arms sales to Taiwan, US exercises with South Korea and China's relationships with Iran and North Korea could all exacerbate tensions. US security treaties with Japan, the Republic of Korea and the Philippines also mean that if these countries miscalculate their responses to China, the US could be brought into the ensuing conflict. Managing the Chinese-American bilateral relationship is likely to be extremely time- and resource-consuming, with the potential rise of India from 2030 onwards constituting a significant complication. Canada has fewer binding obligations with Asian countries and, as a result, is likely to continue to be less constrained by its treaties than the US.

9 Rogers, S. (2012), 'US Debt: How Big Is It and Who Owns It?', available at http://www.guardian.co.uk/news/datablog/2011/jul/15/us-debt-how-big-who-owns

10 Figures for 2011 from US Census Bureau, available at http://www.census.gov/foreign-trade/balance/c5700.html

"US involvement in the Middle East is unlikely to alter significantly, as the region will almost certainly continue to have a significant bearing on global stability and security."

Canada may continue to reject claims over rights of navigational passage

Regional integrity

The Northern American region will almost certainly remain one of the most stable in the world and the threat of major instability or conflict in the region is very low – but the threat from terrorism will probably endure. Though diverse, the US has a strong culture and sense of national identity and it is highly unlikely that any state will secede from the US – although a number of organisations seeking independence for their states do exist. Similarly, it is likely that Canada will retain its territorial integrity, although the possibility of a province or territory gaining independence cannot be wholly discounted. The populations of Bermuda and St Pierre and Miquelon are likely to choose to remain dependent territories of the UK and France respectively so long as their prosperity and way of life is maintained. Greenland, however, is likely to have chosen independence, or some lesser form of home rule, by 2045. There is likely to be competition for influence in Greenland, perhaps particularly from China, especially if – as is expected – melting ice opens up Greenland's exclusive economic zone. It is also possible that Greenland will seek to join one or more of the North American Free Trade Alliance, the EU and NATO.

The Northern American Arctic

The Arctic is likely to be an increasingly important region for the US and Canada out to 2045, particularly as melting ice opens areas for mining and hydrocarbon extraction, as well as shipping. Canada will probably continue to emphasise the importance of the Arctic to its national interests and may continue to reject US and Danish claims over rights of navigational passage within its exclusive economic zone. Despite these disagreements, it is likely to maintain good relations with both countries. Canada and the US are likely to reach agreement on a range of Arctic issues, particularly over gas and oil distribution pipelines from the Arctic to the markets of Northern America. The US may be reluctant to assert its sovereignty over disputed areas of the Chukchi Sea with Russia and may find controlling fishing within the Bering Sea challenged by several countries if the region continues to be a significant source of fish. Although Russia sees the Arctic as an area of key national interest, open conflict between Russia and Northern American countries is highly unlikely. While Greenland's economy and political influence is likely to be relatively small, its strategic location and mineral resources (particularly uranium and rare earth elements) mean that it is likely to be an important partner for both Canada and the US.

Defence and security implications

- While Northern America's economic outlook is positive, US debt could grow, with significant ramifications for its future.
- Although China is likely to surpass the US in terms of GDP, the US is still likely to remain, militarily, the most powerful country in the world.
- A reduced need for Middle Eastern oil is unlikely to alter significantly the US commitment to the region, which will almost certainly continue to have a significant bearing on global stability and security.
- NATO is likely to remain the key security alliance for Northern American countries, although US (and possibly Canadian) commitments elsewhere in the world may mean that European countries will have to take on more of the burden of maintaining security in their region.
- There are a number of issues and treaties which may involve the US and China in armed conflict – with potentially dire consequences regionally and globally.
- The Arctic is likely to be an increasingly important region for Northern America. The US and Canada (and possibly Greenland) are likely to grow military capabilities that can operate there.

1 Anguilla
2 Antigua and Barbuda
3 Argentina
4 Aruba
5 Bahamas
6 Barbados
7 Belize
8 Bolivia
9 Brazil
10 British Virgin Islands
11 Caribbean Netherlands
12 Cayman Islands
13 Chile
14 Colombia
15 Costa Rica
16 Cuba
17 Curaçao
18 Dominica
19 Dominican Republic
20 Ecuador
21 El Salvador
22 Falkland Islands
23 French Guiana
24 Grenada
25 Guadeloupe
26 Guatemala
27 Guyana
28 Haiti
29 Honduras
30 Jamaica
31 Martinique
32 Mexico
33 Montserrat
34 Nicaragua
35 Panama
36 Paraguay
37 Peru
38 Puerto Rico
39 Saint Kitts and Nevis
40 Saint Lucia
41 Saint Vincent and the Grenadines
42 Saint Maarten
43 Suriname
44 Trinidad and Tobago
45 Turks and Caicos Islands
46 United States Virgin Islands
47 Uruguay
48 Venezuela

Latin America and the Caribbean

Latin America and the Caribbean are likely to remain politically and economically fragmented, with individual countries pursuing bilateral relationships rather than forming a strong unified bloc. Brazil and Mexico are likely to show the strongest growth in the region, with both countries likely to be major global economies (in terms of GDP) by 2045. Rising sea levels and extreme rainfall are likely to expose a number of large and populous cities in coastal regions around South America to additional flooding risk. Socially, weak governance is likely to continue to inhibit progress in a number of countries, with the growing consumer class being increasingly vocal in its challenge to regimes. Some Latin American countries are highly likely to have mature military-industrial complexes and armed forces capable of performing on the global stage by 2045. Regional stability is highly likely to endure, although producing and globally distributing narcotics will almost certainly continue, with an increasing 'home market'. However, the emergence of a fully-fledged narco-state is unlikely.

Political and economic fragmentation

With a population as large as that of the EU, the Latin American and Caribbean region is characterised by a diverse economic scale, political orientation, language, history and culture. While there is a desire for a strong pan-regional organisation, efforts to create one have not been realised. It is likely that the region will remain a loose community of countries rather than becoming an institutionalised federal entity. While sub-regional organisations such as CELAC, CARICOM and Mercosur[1] are likely to continue, they are unlikely to develop into powerful, unified institutions. This makes it probable that relationships with external actors will be conducted on a bilateral basis.

Global economic powerhouses

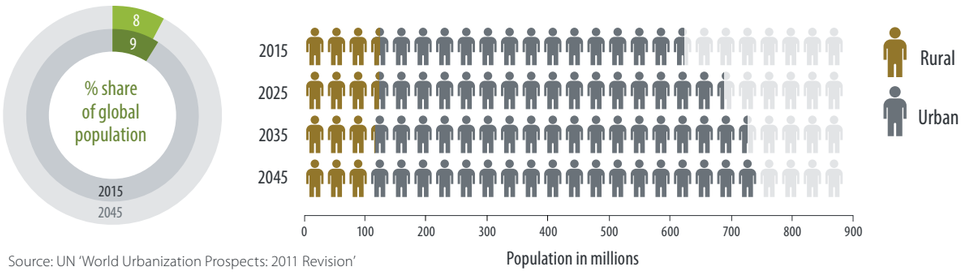
The region's most powerful economies, Brazil and Mexico, are likely to be among the world's ten largest economies by 2045. Both countries possess natural resources, including hydrocarbons, which have the potential to be very lucrative. However, exploiting these resources has, to date, proved quite challenging. For example, Mexico is estimated to have the same amount of oil as Kuwait. However, its state-owned oil company has lacked the expertise to develop Mexico's oil fields, and the country's constitution has prevented private and public companies from entering into joint ventures.[2] Mexico therefore has to import more than 40% of its petrol from abroad,[3] – although this could be changing. Similarly, due to a lack of refining

1 CELAC: Community of Latin American and Caribbean States. CARICOM: Caribbean Community. Mercosur: an economic and political agreement between Argentina, Brazil, Paraguay, Uruguay and Venezuela, promoting free trade.

2 Thomson, A. (2013), 'Rusty Wheels of Pemex Require Much Oiling', available at http://www.ft.com/cms/s/0/0d5a467c-9bb0-11e2-8485-00144feabdc0.html#axzz2VBhfGoiL

3 Nedelec-Lucas, C. (2012), 'Unrefined Company: PEMEX and Gasoline Imports', available at http://gbroundup.com/2012/08/07/unrefined-company-pemex-and-gasoline-imports

A growing population living in the urban environment



Source: UN 'World Urbanization Prospects: 2011 Revision'

"Trade routes and choke points will probably become increasingly important to Latin American countries."

capacity, Brazil's state oil company, Petrobras, had to increase its petrol imports by 90% in 2012 to meet consumer demand. Due to the Government setting the price of oil, Petrobras had to sell on the fuel to the public at a huge loss.[4] Unless such issues are resolved, Brazil and Mexico could find themselves in the position of merely being resource providers for other economies, stopping their progress towards becoming economic and political powers.

Foreign investment

The US is likely to remain the pre-eminent external economic power in the region, with many countries deepening their economic ties with it. Compared to the US, China is a comparatively minor regional provider of foreign direct investment.[5] To date, China has concentrated its regional investment on Peru, Colombia and Ecuador, buying vast amounts of commodities and providing state loans. These purchases and loans often require the borrower to open up their internal markets to cheap Chinese goods, reducing the demand for domestic products. Out to 2045, China's relationship with the region is likely to remain an often uneasy marriage of convenience, with some Latin American countries resenting the conditions attached to China's financial involvement. China's interest will almost certainly remain economic and any move to influence Latin American politics, social norms or wider development will almost certainly be in the context of ensuring continued access to markets and commodities. Trade with Asia more generally is likely to increase, particularly for the 'Pacific Alliance' countries in the west of Latin America (Chile, Colombia, Mexico and Peru). Trade routes and choke points, such as the Malacca Straits, will probably become increasingly important to Latin American countries – some form of military presence in the area may be necessary to assist with policing. EU countries are likely to continue to invest in the region primarily on a bilateral, rather than collective, basis (although some EU negotiations are likely to continue), increasing their trade links out to 2045.

Migration

Latin American economies currently struggle to produce a sufficient number of skilled and educated workers. This is likely to continue out to 2045, attracting economic migrants from Europe and elsewhere into the region.[6] If Europe's economic problems continue, this flow is likely to increase, leading to some significantly-sized European communities in the region, primarily working in well-paid management or technical jobs. In stable countries, this is likely to bring new business opportunities, but in those less stable, it may also mean that countries such as Portugal and Spain could have significant 'populations at risk'. In extreme (but unlikely) cases, foreign nationals living and working in Latin America may need protecting or evacuating if severe natural disasters or rising political tensions occur.

4 This measure resulted in the refining sector of Petrobras posting a 2012 loss of some 22.9 billion Reais (US$ 11 billion). MercoPress (2013), 'Petrobras Still Going Strong but 2012 Low Profits and High Debt Pound on Prospects', available at http://en.mercopress.com/2013/02/05/petrobras-still-going-strong-but-2012-low-profits-and-high-debt-pound-on-prospects

5 OCO (2012), 'Latin America's Decade? FDI Trends and Perspectives', available at http://www.ocoglobal.com/uploads/default/files/Latin_Americas_Decade_-_FDI_trends_and_perspecives.pdf

6 The number of European immigrants to Brazil rose sharply by 50% to almost 1.5 million in the first half of 2011. Emerging Market Musings (2011), 'Brazil's Brain Gain Not Enough', available at http://emergingmarketmusings.com/2011/12/11/brazils-brain-gain-not-enough/

The consumer class

Latin America and the Caribbean are likely to see an expanding consumer class out to 2045. The consumer class has grown by 50% in the last ten years, and now comprises 30% of the region's population, with growth likely to continue.[7] From a regional perspective, this growth in relative wealth is likely to have a positive, stabilising effect, as more people feel that they are prospering within the current system. However, with greater access to the Internet, a more confident and affluent consumer class is likely to be increasingly vocal in its scrutiny of governing regimes. The growing consumer class, particularly in larger and more affluent countries like Brazil and Argentina, is also likely to find itself increasingly beset by health problems commonly found in western countries, such as obesity and related illnesses like type-two diabetes – 18% of the Argentine population is currently obese.[8] Consequently, workforce productivity could be lowered and a rise in healthcare costs could burden these countries' economies.

Climate

Average temperatures are projected to increase by several degrees across the region, particularly in the south, but less so in the tropics. Heatwaves are expected to increase in frequency and intensity over much of the region. Annual precipitation projections indicate a drying over the eastern Amazon basin, Brazil and southern Chile, with increases over north western South America. Sea-level

"Growth in relative wealth is likely to have a positive, stabilising effect, as more people feel that they are prospering within the current system."

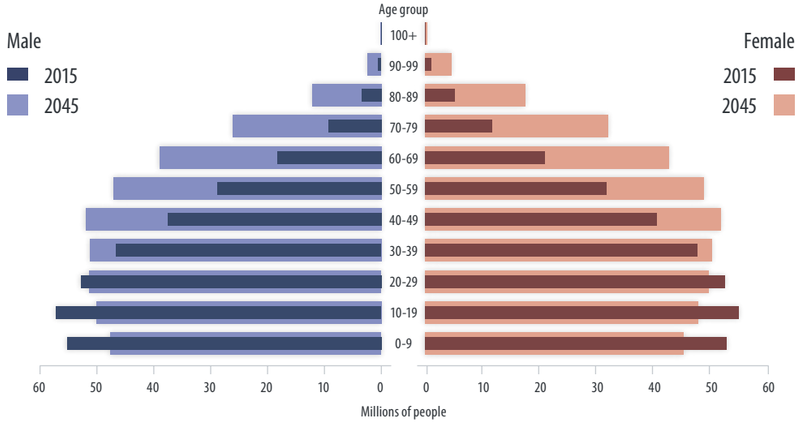
7 World Bank (2012), 'Latin America: Middle Class Hits Historic High', available at http://www.worldbank.org/en/news/feature/2012/11/13/crecimiento-clase-media-america-latina

8 Hill, A. (2011), 'Expanding Waistlines - Obesity in Argentina', available at http://www.argentinaindependent.com/currentaffairs/newsfromargentina/expanding-waistlines-obesity-in-argentina/

Santiago, Chile. An example of growing urban prosperity in the region

An ageing population

Population by ten-year age group and sex



Source: UN (2012), 'World Population Prospects: The 2012 Revision'

rise, combined with potential increases in extreme precipitation events, could increase the exposure of a number of large and populous cities in coastal regions around South America.

Water

The rainfall changes across the region, and a projected continuing retreat of glaciers due to increasing temperatures, is likely to affect the availability of freshwater across South America. This could have significant impacts on agricultural productivity, water for hydro-energy (which meets around 60% of domestic energy demand) and ecosystem health and diversity. Continued retreat of glaciers is likely to increase glacial runoff in the short-medium term, but as the glacial mass reduces, reductions in glacial-water availability could occur. Drought events in the region are projected to occur more frequently, particularly in the Amazon.

Agriculture

In the south eastern part of South America, crop yields (such as soy, maize and wheat) are projected to either remain stable or slightly increase out to 2045, due to more favourable temperature conditions. However, water limitations and an increase in extreme weather events may reduce crop yields. In tropical regions, the changing climate is likely to reduce crop production, particularly affecting crops such as beans, corn, cassava and coffee.

Marine ecosystem productivity

The future impact of climate change on the Humboldt Current (one of the world's most productive marine systems) is uncertain, but fisheries could be damaged. Coral reefs, and the marine ecosystems and fisheries they support, have been identified as 'at risk' due to increasing temperatures and ocean acidification. This may reduce the productivity of reefs to the north of the region, affecting those who depend on them for work and food.

Governance

For its economies to grow, the region will probably have to strengthen its political institutions, many of which currently face considerable challenges in delivering effective governance, tackling underdeveloped commercial legislation, employment law and fiscal credibility.

Without action, these issues are likely to continue to have a damaging effect on levels of foreign direct investment, limiting the region's economic potential.[9] There are some indicators that the region's governance is improving. For example, in 2001, Argentina's civil government dealt with the largest sovereign debt default in history. Despite subsequent civil unrest, Argentina did not revert to military rule, evidence that civilian institutions and government have taken hold. Nevertheless, corruption in Latin America and the Caribbean is likely to remain a significant issue, with Transparency International assessing a number of the region's countries as having a serious corruption problem.[10]

Military development

Although defence expenditure in Latin American countries overall remains low in global terms,[11] by 2045 Brazil is likely to have the ability to project power globally. Brazil is buying more military capability and modernising its military-industrial complex. It has recently stated its intention to build nuclear- as well as conventionally-powered submarines. While the degree to which Brazil would wish to use these new assets for power projection remains unclear, it is apparent that the capabilities needed for Brazil to play a large part in global security will almost certainly exist within (approximately) the next 15 years. Like Brazil, Argentina also aspires to develop nuclear propulsion technology to power "vessels or submersibles" and has made a commitment that "the current 0.5% of GDP [spent on defence] will be increased in coming years to reach 1.5%."[12]

9 The World Bank's 'Ease of Doing Business Rankings' places the region's two largest economies (Brazil and Argentina) at 116th and 126th respectively, out of 189 nations evaluated. Doing Business (2013), 'Economy Rankings', available at http://www.doingbusiness.org/rankings

10 Paraguay ranks 150, Venezuela 160, Guyana 136, Nicaragua 127, Mexico 106. Chile, by contrast, is rated 22nd out of 177 countries. Transparency International (2013), 'Corruption Perceptions Index 2013', available at http://www.transparency.org/cpi2013/results

11 SIPRI (2012), 'Trends in World Defence Expenditure 2012', available at http://books.sipri.org/files/FS/SIPRIFS1304.pdf

12 MercoPress (2010), 'Argentine [sic] to Increase Budget Defence [sic] 50%, Recovering Losses of Falklands War', available at http://en.mercopress.com/2010/09/01/argentine-to-increase-budget-defence-50-recovering-losses-of-falklands-war

Brazil is increasing investment in defence capability

Although Argentina's military is currently geared towards local defence and security, an increase in defence spending could see more capable armed forces develop over time. Given the country's sensitivities regarding the recent history of its military, however, lavish defence expenditure and large armed forces are likely to remain unpopular propositions for most Argentines. Other Latin American countries may also develop aspirations for global power projection and political influence out to 2045.

Although tension between some countries is likely to endure out to 2045, Latin America is unlikely to see an 'arms race'. While increasingly capable militaries and a maturing military-industrial complex will almost certainly be features of the larger countries, particularly within South America, a regional state-on-state conflict is unlikely. Although such wars have taken place comparatively recently, the increasingly interdependent nature of regional trade, as well as diplomatic activities, provides strong incentives for peace.[13]

No country in the region has made a public declaration of its intent to acquire nuclear weapons. Indeed, some have enshrined non-nuclear armed clauses in their constitutions or signed up to binding treaties. However, both Brazil and Argentina have pursued such capabilities in the past, albeit when they were under military dictatorships. By 2045 a number of countries in the region will almost certainly have both the resources and the latent expertise to pursue a nuclear weapons programme should a political imperative emerge.

Out to 2045, many Latin American countries are likely to become more globally engaged. Several countries could actively use their militaries more internationally, probably in peace support and security assistance roles. Brazil, for example, has a programme of military cooperation and development assistance along the African Atlantic coast.

Similarly, Chile has recently offered to become more involved in peace support operations (including with the EU) and Columbia has expressed a desire to form a link with NATO. As Latin American countries become more engaged, they are likely to seek greater influence in international institutions – including the UN Security Council.

The region produces nearly all of the world's coca leaf

Narcotics

A recent UN report stated that Colombia, Peru and Bolivia are responsible for producing almost 100% of the world's coca leaf.[14] Narcotics intended for Northern American and European markets will probably continue to be smuggled through Central America and the Caribbean. Drug cartels are highly likely to remain a significant threat to social and political stability throughout Latin America and the Caribbean. As the region's own consumer class becomes more affluent, there is likely to be an increase in the 'home' drugs market. Some studies have suggested that "Brazil is now the world's number one market for crack cocaine - with at least 1 million hard-core users."[15] It is unlikely that a full-blown narco-state – a region controlled by drug-cartels, with non-existent law-enforcement – will develop in the region, given the improved nature of domestic drugs policy and US interests. However, smaller countries such as Belize, El Salvador and Panama are likely to remain highly vulnerable to the influence of drug cartels, as well as the related crime and corruption that such influence brings.

13 For example, the Cenepa War of 1995 between Peru and Ecuador, which resulted in approximately 500 casualties.

14 UN Office on Drugs and Crime (2011), 'World Drug Report 2011', available at http://www.unodc.org/documents/data-and-analysis/WDR2011/World_Drug_Report_2011_ebook.pdf

15 Ghosh, P. (2013), 'Brazil Ensnared In Crack Cocaine Epidemic: Sao Paulo takes Desperate Measures', available at http://www.ibtimes.com/brazil-ensnared-crack-cocaine-epidemic-sao-paulo-takes-desperate-measures-1014090

Defence and security implications

- A mature military-industrial complex will probably be a feature of the wealthier Latin American countries by 2045.
- While a Latin American arms race is unlikely, some countries are likely to have much more capable armed forces by 2045 than at present, with world-class capabilities in some areas.
- A regional state-on-state conflict is unlikely to occur.
- The emergence of a nuclear-armed country in Latin America by 2045 cannot be ruled out, despite existing treaties to the contrary. The resources and knowledge to create nuclear weapons will almost certainly be present in a number of countries in the region.
- More Latin American countries and their militaries are likely to become increasingly active internationally.
- It is not likely that a narco-state will emerge in Latin America or the Caribbean by 2045, but drug cartels are likely to continue to have significant influence in a number of countries for the foreseeable future.

1 Albania
2 Andorra
3 Austria
4 Belarus
5 Belgium
6 Bosnia and Herzegovina
7 Bulgaria
8 Channel Islands
9 Croatia
10 Cyprus
11 Czech Republic
12 Denmark
13 Estonia
14 Faeroe Islands
15 Finland
16 France
17 Georgia
18 Germany
19 Gibraltar
20 Greece
21 Holy See
22 Hungary
23 Iceland
24 Ireland
25 Isle of Man
26 Italy
27 Latvia
28 Liechtenstein
29 Lithuania
30 Luxembourg
31 Malta
32 Monaco
33 Montenegro
34 Netherlands
35 Norway
36 Poland
37 Portugal
38 Republic of Moldova
39 Romania
40 Russian Federation
41 San Marino
42 Serbia
43 Slovakia
44 Slovenia
45 Spain
46 Sweden
47 Switzerland
48 TFYR Macedonia
49 Ukraine
50 United Kingdom

Europe

Europe is likely to remain a substantial part of the global economy, with the euro and the single market still likely to exist by 2045. EU membership is likely to expand, although it is unlikely that all countries who wish to join will be included. The effects of climate change are likely to be less severe in Europe than in most other regions, although increased water scarcity in the south may limit agricultural productivity there. Energy consumption is likely to decrease out to 2045, although hydrocarbons will probably continue to be the continent's main source of fuel. Europe is likely to face a range of security challenges, but disagree internally over how to address them. As the US focusses increasingly on Asia, Europe will almost certainly be expected to make a greater contribution to its own security. Russia is likely to continue to be a major power, maintaining a substantial capability for regional intervention by 2045. China and Europe are unlikely to view each other as threats and may become partners in managing future crises.

The European economy

Europe is likely to remain a substantial part of the global economy, although the European economic area is likely to face internal structural problems. As Europe already has a mature economy, opportunities for further development are comparatively few (relative to the developing countries), which may mean that growth prospects remain low. The Organisation for Economic Cooperation and Development (OECD) estimates that there will be annual growth of 1.5-2% by 2045.[1] Nevertheless, Europe is still likely to have among the highest levels of consumption and wealth in the world – the EU single market is likely to remain a globally important and attractive trade area. Despite competitive pressures, there is likely to continue to be a strong political and economic relationship between the EU and US. This is likely to be driven by common values, extensive financial interdependence and shared interests between EU- and US-based multinational corporations.

The euro and the European single market will probably continue out to 2045, but are likely to face continuing economic challenges. Some countries may withdraw (or be forced to withdraw) from the single currency by 2045. It is possible that the euro will expand to take in new members, perhaps from EU accession countries. Further integration is likely to occur to bolster economic recovery and prepare for future crises. However, political and economic tensions leading to the collapse of the euro cannot be ruled out. This would be a severe setback for European integration and have a significant impact on the global economy.

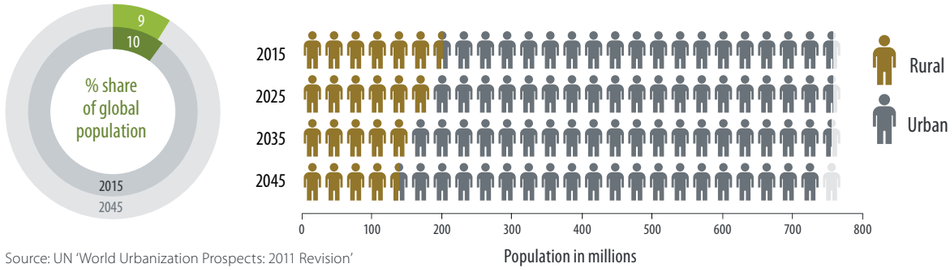
EU membership

By 2045, it is likely that the EU will include most of the countries in the western Balkans. Turkey is likely to become increasingly important to European security, as the size, capability and increasing modernisation of its armed forces means that it may have one of the more capable militaries in Europe, as well as the Middle East.[2] Despite Turkey's importance,

1 OECD (2011), 'An Economic Projection to 2050: The OECD ENV-Linkages'

2 IISS (2013), 'The Military Balance 2013'

A declining population with fewer living in the rural environment



Source: UN 'World Urbanization Prospects: 2011 Revision'

"Diaspora Muslim communities in Europe are likely to be increasingly affected by intra-faith discord in the Middle East."

it may not receive full membership of the EU by 2045, as existing members are likely to fear high costs of integration and disruptions to local labour markets. These reasons may also rule out other countries wishing to join the EU. The EU is likely, however, to seek far-reaching trade and cooperation agreements with these countries to promote stability.

Urbanisation, diversity and religion

Urbanisation is likely to continue, with super-cities straddling national boundaries. More than two thirds of the European population currently live in cities and urbanisation is likely to increase out to 2045, with large trans-national urban regions developing. The UN estimates that Europe will have more than 20 such areas by 2045, with a substantial element of south-west Germany, most of the Netherlands and much of Belgium forming a single agglomeration.[3] Urban areas across Europe are likely to contain pockets of social deprivation, often containing a high proportion of migrants.

Extensive immigration and mobility of people within Europe is likely to lead to increasingly multicultural societies, with a trend towards secularism. However, local communities with strong religious beliefs are also likely to continue to exist. The majority of Europeans will probably tolerate integration and immigration, rather than embrace it, reverting to a national or regional (rather than European) identity in times of stress. The Islamic population of Europe is expected to continue to grow, exceeding 58 million by 2030 (8% of the total population),[4] but with Christian traditions likely to remain dominant. Diaspora Muslim communities in Europe are likely to be increasingly affected by intra-faith discord in the Middle East. In particular, tension between Sunni and Shia Islam could spread. In 2012, Belgium's largest Shiite mosque was fire-bombed by hard-line Sunnis.[5] While there may be an increase in incidents, particularly in response to events in Asia and the Middle East, it is unlikely that large-scale violence between the different sects will occur in Europe itself, not least because of the small number of Shias.[6]

Family sizes

European family sizes are likely to remain small, with birth rates expected to remain under the replacement level of 2.1 children for each woman. Population growth is therefore only likely to occur due to immigration. The UK and France are likely to have the highest increases

3 UN Population Division (2011), 'World Urbanisation Prospects, 2011 Revision', available at http://esa.un.org/unup/

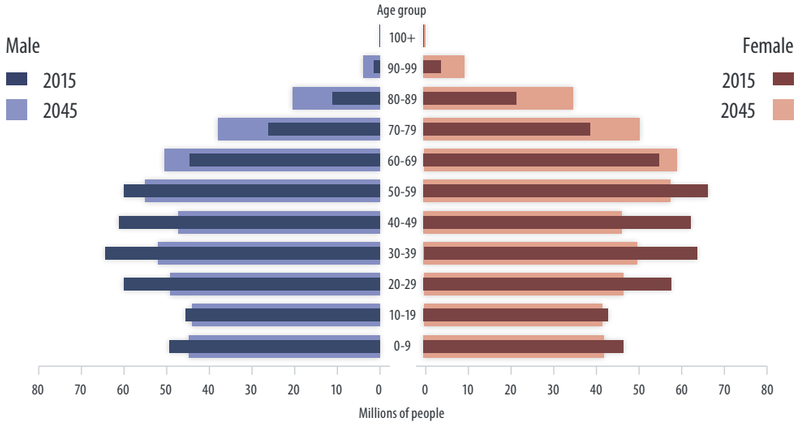
4 Pew Research Centre (2011), 'The Future of the Global Muslim Population', available at http://www.pewforum.org/files/2011/01/FutureGlobalMuslimPopulation-WebPDF-Feb10.pdf

5 The Economist (2012), 'The Sword and the Word: In the Struggle Between the Two Strands of Islam, the Sunnis are on the Rise', available at http://www.economist.com/node/21554513

6 In the UK, Shiite leaders claim their number is approximately 15-20% of local Muslims, whereas government figures put the proportion at 5%. See Puelings, J. (2010), 'Fearing a 'Shiite Octopus': Sunni – Shi'a Relations and the Implications for Belgium and Europe', available at http://www.egmontinstitute.be/paperegm/ep35.pdf

An ageing population

Population by ten-year age group and sex



Source: UN (2012), 'World Population Prospects: The 2012 Revision'

in population in the timeframe, leading to increased infrastructural and environmental pressures in their urban regions.[7] Conversely, significant parts of central, eastern and southern Europe are highly likely to face demographic decline and stagnation.[8]

Climate

Temperatures will almost certainly increase across the region, with a rise in extreme weather events such as the 2003 heatwave (which caused over 35,000 deaths). Rainfall patterns will probably change, with northern Europe becoming wetter in winter and Mediterranean regions becoming significantly drier, particularly in summer months. Droughts are likely to increase in number, particularly in the central and southern regions. Rising sea levels could have significant impacts for several major low-lying cities particularly in the Netherlands.

Agriculture and fisheries

The climatic effect on agriculture will probably have a significant impact on future yields. Significant decreases in yields in the southern regions are expected due to water shortages and increasing temperatures, with small decreases in the central regions, and increases in the north. Europe is likely to remain self-sufficient for arable and livestock production, although many European people may be concerned about food security. Technological advancements, such as more efficient desalinisation plants, are likely to mitigate water shortages in the Mediterranean

Shock:
Rise of a European power

If a European country financially out-performed the rest of the EU to a significant extent, domestic political concerns could prompt the country's leaders to use its leverage to dominate Europe not only economically but also politically, severely challenging the EU's cohesion. In such a situation, Europe could split between those countries who are dependent on the large power and those who resent its influence. There is a risk that NATO could become less effective, as European countries may place loyalty or opposition to the economic power above any other alliances.

7 UN Population Division (2013), 'World Population Prospects, 2012 Revision', available at http://esa.un.org/wpp/Documentation/publications.htm

8 *Ibid.*

There is likely to be an increase in renewable energy capabilities

area, and genetically modified crops are likely to become increasingly widespread (despite opposition from environmentalists), allowing continued production as temperatures rise and rainfall patterns change. Warming of the oceans, due to climate change, may affect fish migration and could lead to the collapse of some fisheries in European waters. There may also be tension over fishing rights, particularly in the north Atlantic, as non-European fishing fleets seek to operate in the area.

Energy

European energy consumption is likely to gradually decrease out to 2045 as a result of wide-scale efficiency initiatives, although there will probably be an increase in energy used for heavy transportation.[9] Hydrocarbons are likely to continue to be the continent's main source of energy. Although there is likely to be an increase in renewable energy capabilities, nuclear power is likely to continue to be the primary source of power-generation in some European countries and its use may become more widespread if safety concerns can be addressed. Europe is likely to remain dependent on imports to meet a substantial proportion of its energy requirements, potentially still relying on imports from Russia and the Middle East by 2045. The US, however, is also likely to become an important European supplier of hydrocarbons within the next two decades. Nevertheless, reliance on energy imports is likely to mean that Europe will remain vulnerable to disruptions to its energy supply.

European security

Europe is likely to face a range of security challenges, but disagree internally over how to address them. However, on a sub-regional level, defence cooperation is likely to increase to maximise scarce resources. Operational responsibilities (such as air and sea surveillance) will almost certainly continue to be shared, and resources pooled. Military capabilities are also likely to be jointly developed and procured. In an increasingly globalised world, no European country is likely to be able to handle major security issues in isolation. Such challenges may, for example, come from: more sophisticated trans-national criminals and terrorists using new technologies; resource-security; and vulnerabilities in the cyber environment. Europe-wide decisions on foreign and security policy are likely to remain a source of tension, with decision-making unlikely to proceed rapidly, even in times of crisis. Although the EU will probably continue to be one of the world's three largest economies by 2045, its lack of a central military capability means that it is likely to be comparatively weak as a global actor. European countries are, however, likely to continue to agree on the necessity for supporting and using institutions, such as the UN and the G20, to maintain global stability and security.

As the US focusses increasingly on Asia, European countries will almost certainly be expected to make a greater contribution to their collective security. NATO is likely to endure and remain globally significant, but its character will probably change. Most European NATO members are likely to find it difficult to deploy and sustain military power outside Europe without extensive US support. Smaller European countries are only likely to be able to use their armed forces in a coalition. Exceptions to this trend will probably be the UK and France, who are both likely to continue to be nuclear-armed powers by 2045, and capable of independent operations. European countries' defence spending is unlikely to increase significantly unless a major threat develops, with an emphasis on technology and professionalism rather than weight of numbers. This lack of volume may lead to an increased number of security contractors augmenting European countries' forces in overseas operations. NATO is likely to remain the bedrock of European countries' security. However, as US force levels decline and the US is forced to prioritise, its role in NATO may reduce. This could lead to the Alliance taking on the character of a European-based defence organisation. In particular, European NATO-members and the EU may have to take a more active role in managing Russian influence at a time when Russia's military is re-emerging as an instrument of power. Similarly, European countries are likely to be the principal provider of stability in the Balkans.

Russia

Russia is likely to continue to be a major regional power, maintaining a substantial capability for regional intervention by 2045. Russia's permanent membership of the UN Security Council, geographical size, large energy reserves and substantial armed forces are likely to ensure its continued status as a regionally (and, to some extent, globally) influential power by 2045. The Russian political system will probably remain authoritarian, even after President Putin's tenure ends. Restoring Russia's status as a 'great power' is likely to remain a key political objective for the country. Russia will almost certainly seek to influence its near abroad with a mixture of hard and soft power. Geopolitical considerations, domestic concerns and economic pragmatism are likely to continue to characterise Russia's foreign policy out to 2045.

The Russian economy may have a better rate of growth than some European countries in the short-term, but this is unlikely to continue out to 2045. Russia's economy is almost certain to remain smaller than the EU's as a whole. Although energy exports to Asian markets are likely to have increasing importance, Europe will probably remain Russia's primary economic focus. The

> *"The EU may have to take a more active role in managing Russian influence at a time when Russia's military is re-emerging as an instrument of power."*

Shock:
Collapse of a major power

An authoritarian country, held together by an oppressive, unrepresentative regime could conceivably collapse following a period of prolonged under-investment in civil institutions, infrastructure and healthcare, combined with an economic decline exacerbated by international isolation and sanctions. If such a country already contained a number of different sub-national groups, civil war could occur, followed by fragmentation into several new countries with severe consequences for the global economy and regional security and stability.

9 International Energy Authority (2013), 'World Energy Outlook 2013', available at http://www.worldenergyoutlook.org/

Part 2

"With shared interests China and the EU may become partners in future crisis management."

country is almost certain to face a number of challenges, such as an ageing society, environmental degradation, corruption, under-investment and narrow democratic institutions. Russia may also be hindered in fulfilling its economic potential by inefficient allocation of resources and chronic under-investment. In the long term, this may make it harder to maintain social stability.

Russia's growing Islamic population could challenge the traditional Slavic identity and continuing unrest driven by separatists in its outlying regions could exacerbate the government's security concerns. At the same time, the generation of Russians born after the Cold War may demand greater representation and reduced corruption. However, major reforms of the political system and the institutional economic framework are not likely unless there is a change in Russia's style of government. Without reform, however, Russia is likely to experience a gradual economic decline and there is the potential for extensive political and social unrest. A Russian collapse or fragmentation would have serious consequences for the global economy and would be likely to have severe implications for the stability of neighbouring countries, including those in eastern Europe.

China

With shared interests such as stability in the Middle East and security of trade routes, China and the EU may become partners in future crisis management. Europe and China will probably have a primarily economic relationship, centred on the EU and the single market. The Chinese market will almost certainly be an important one for Europe, just as access to European consumers and capital is likely to be important for Chinese growth. Chinese tourism to Europe is also likely to significantly increase, constituting an important part of the European tourist industry by 2045. Militarily, China and Europe are unlikely to see each other as direct threats, although European countries may continue to view China with caution because of differences on human rights, systems of governance and encroachment on intellectual property rights.

Defence and security implications

- Countries in Europe are likely to agree on the broad nature of security challenges facing the continent, but will probably disagree over how to address them. However, on a sub-regional level, defence cooperation is likely to increase to maximise scarce resources. Operational responsibilities (such as air and sea surveillance) will almost certainly continue to be shared, and resources pooled. Military capabilities are likely to be jointly developed and procured.
- European countries' defence spending is unlikely to increase significantly without a major threat.
- NATO is likely to remain the key organisation for military crisis management, although its cohesion may be challenged by diverse threat perceptions, a US focus on Asia and internal disagreement on its global role. The Alliance could be reinvigorated by the need to band together to address a deteriorating security situation in Europe's near abroad.
- Russia is likely to remain an influential regional power. Its assertiveness and power-politics may cause future European security challenges.

Global Strategic Trends

Middle East and North Africa

Over the next 30 years, the Middle East and North Africa (MENA) are likely to remain volatile areas, with high potential for tension and some violent conflict. The aftermath of the Arab Uprisings of 2011 may still resonate in some countries, with civil unrest likely. Identity politics and sectarianism will almost certainly be key characteristics of the political landscape, constituting a serious challenge to good governance. Countries in MENA are unlikely to be able to break the cycle of power politics, patronage, religious tension and authoritarianism. Social, environmental and economic issues will probably continue to threaten the region's stability out to 2045, including an under-employed young population, a decline in natural energy resources and the effects of climate change.

Political reform

The popular uprisings and protests that began in 2011 – known as the 'Arab Spring' – expressed a demand for more freedom and reform of the political systems across the region. Activists were able to exploit social media, something that existing, rigid state structures initially found hard to cope with. However, while this demand is likely to increase over the next 30 years, it will not necessarily lead to major political reform across the region. Activists often struggle to translate short-term revolutionary action into lasting, concentrated authority. Creating flourishing democracies in a number of Middle Eastern and North African countries faces a range of problems,[1] but there is agreement that a lack of an established civil society is preventing sustainable change. There is also a broad consensus that a willingness by authoritarian regimes to crack down on popular uprisings using force is preventing real change from occurring. Social and economic pressures are likely to increase the demand for change in the region, driving violent unrest out to 2045. Identity politics have made a resurgence across the region which is likely to continue, with many people defining themselves and their relationship with the state by their ethnic or religious identities. As witnessed in Iraq and Syria, sectarian differences are being exploited as a justification for violence – a trend that is likely to continue out to 2045.[2] Governments in MENA are using sectarian identities as a basis for defining their power and distributing resources, meaning conflicts are often superficially sectarian in nature even if they are actually driven by power politics and resources.

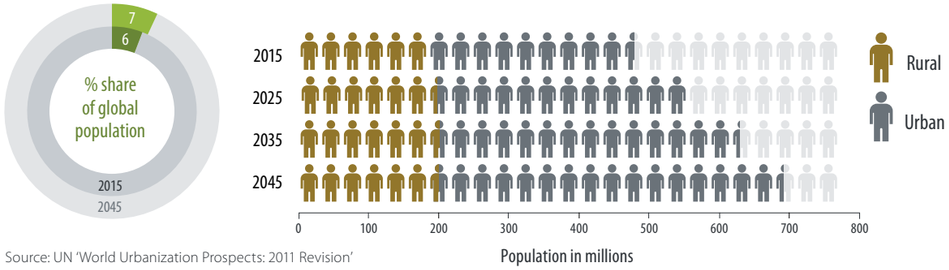
Balance of power

It is highly likely that over the next 30 years there will be shifts in the balance of power across the region. For example, it is possible that the recent development in Iran's relationship with the US will have a major knock-on effect within the Middle East. The easing of sanctions and acceptance of Iran's development of nuclear energy could see

1 Burnell, Peter J. (2013), 'Democratisation in the Middle East and North Africa: Perspectives from Democracy Support', available at http://wrap.warwick.ac.uk/55386/1/WRAP_Burnell_7270220-pais-280613-twq2%20%284%29.pdf

2 European Council on Foreign Relations (2013), 'The Gulf and Sectarianism', available at http://www.ecfr.eu/publications/summary/the_gulf_and_sectarianism217

A growing population living in the urban environment



Source: UN 'World Urbanization Prospects: 2011 Revision'

Iran strengthening its position as one of the region's leading powers, and increasing its international cooperation. However, the region will almost certainly remain volatile and the thawing of relations between Iran and the US may be reversed. Out to 2045, it is likely that new drivers will emerge that alter the shape of the region's geo-politics, such as a potential decline in the market for hydrocarbons due to advancements in alternative energy sources.

"MENA's population is expected to increase by around 230 million by 2045 to approximately 670 million."

Regional demographics

Increasing numbers of working-age people are likely to be dissatisfied with employment opportunities, fuelling civil unrest. MENA's population is expected to increase by around 230 million by 2045 to approximately 670 million, with the populations of some countries, such as Yemen, almost doubling during this period.[3] North Africa accounts for about six percent of the world's population, with an average annual growth rate of 1.7%. People of working age are likely to be the largest section of the population, meaning that governments will probably be under pressure to ensure that there are enough jobs to meet people's needs. However, as the economies of many countries in the region are driven by energy production or consumption, they generally lack the necessary economic diversity for sustained growth. Many of the governments in the region are already experiencing significant problems with their youth, who now have better education and more access to information via the Internet, causing them to become increasingly frustrated with their limited opportunities to work and improve their standard of living. This problem is likely to worsen. By 2045, access to information will almost certainly improve, making the population increasingly aware of inequality and their lack of opportunity. Providing work and meeting a growing sense of personal ambition among people of working age are highly likely to be significant challenges for governments across the region. In 2012, for example, North African youths were 3.4 times more likely to be unemployed than adults.[4] These factors are likely to add to growing civil discontent in MENA out to 2045, constituting some of the most likely causes of civil unrest.

Israel's future demographics are unclear, with some predictions suggesting that by 2030 the number of Israeli Jews in the area between the Mediterranean Sea and Jordan River could be in a 44% minority if the current rate of population growth continues (1.8% among Israeli Jews and 2.5% among Palestinians).[5] Many argue that Israel must adopt the two-state solution if it is to preserve itself as a Jewish *and* democratic country. However, others argue the statistics are flawed and the 'demographic time bomb' that faces Israel is a political tool to achieve a settlement. Evidence is inconclusive as to whether Israel's

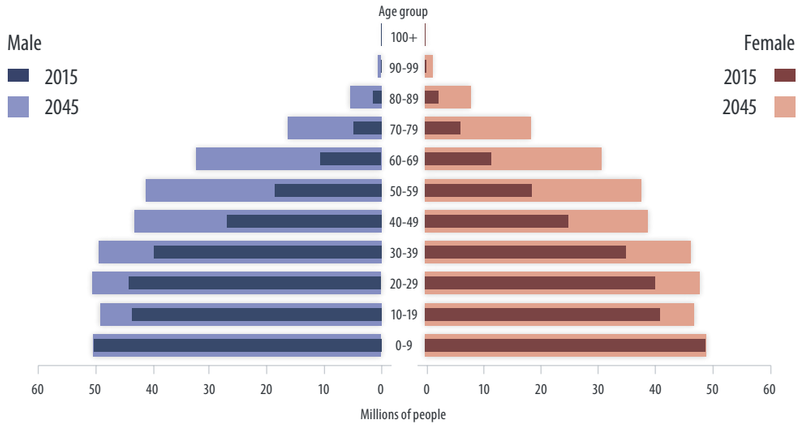
3 UN Population Division (2013), 'World Population Prospects: The 2012 Revision' available at http://esa.un.org/wpp/unpp/panel_population.htm

4 High Level Panel on Fragile States (2014), 'Ending Conflict and Building Peace in Africa: A Call to Action'

5 Israeli Central Bureau of Statistics (2012), 'Statistical Abstract of Israel 2012', available at http://cbs.gov.il/reader/shnaton/templ_shnaton_e.html?num_tab=st02_03&CYear=2012

An ageing population

Population by ten-year age group and sex



Source: UN (2012), 'World Population Prospects: The 2012 Revision'

changing demographics will necessarily force a Middle East settlement or alter the balance of power between Israeli Arabs and Jews, although it is likely that the Israeli Arab population will increase significantly over the next 30 years.

Resources

Most of the region's economies are likely to continue to be centred on exporting hydrocarbons and there is scope for further exploitation. For example, estimates suggest that Libya holds 46 billion barrels of known oil reserves[6] and Israel has recently started exploiting extensive new fields of natural gas.[7] Conversely, Egypt is already a net importer of oil, a situation that is unlikely to change in the foreseeable future.

Energy

It is likely that the majority of MENA's energy will flow towards Asia and Europe, rather than Northern America, out to 2045. China and India, in particular, are likely to increase their dependency on the region's oil to drive their economic development, to the extent that it could be the key factor in their economic progress. MENA already provides more than 70% of China's oil, with Saudi Arabia being its largest supplier – China is second only to the US as a buyer of Saudi Arabian oil.[8] India has long-established relations across MENA, including close ties with both Israel and Iran, and is the fourth biggest consumer of oil in the world, importing around three million barrels of oil per day. Forecasts of India's oil consumption suggest that there could be a particularly steep increase as the gap between India's production and consumption continues to grow. Threats to MENA's stability and its hydrocarbon production could have devastating consequences for Asia's economic growth over the next few decades – policies

"Threats to MENA's stability and its hydrocarbon production could have devastating consequences for Asia's economic growth over the next few decades."

6 Oil and Gas Journal (2011), 'Libya: NATO Dismisses Government Allegations of Air Attacks on Oil Fields', available at http://www.ogj.com/articles/2011/04/libya--nato-dismisses.html

7 Reuters (2014), 'Israel Takes Step Towards Becoming a Gas Exporter', available at http://www.reuters.com/article/2014/02/07/woodside-leviathan-idUSL3N0LB5KU20140207

8 For a local review of growing and 'fruitful' China-Saudi relations see Arab News (2012), 'Working Together for Brighter Future of Saudi -Chinese relations', available at http://www.arabnews.com/working-together-brighter-future-saudi-china-relations

"[The] lack of networked economic interdependence remains a structural weakness for the region."

of non-intervention are likely to be difficult to maintain. As a result, China and India could become more involved in maintaining MENA's regional security.[9] It is possible that the US will reduce its involvement in the region, as it becomes more energy self-sufficient, but it is more likely to maintain a commitment to MENA due to its commitment to countries in the region (including Israel) and because of its strategic military basing in the area. The US's desire to keep the price of oil stable, to avoid shocks to the global economy, is also likely to secure its commitment to the region for some time to come. The EU is likely to continue to be a major importer of Middle Eastern oil. Consequently, EU member states may find themselves increasingly partnering Asian countries in addressing security issues within MENA.

Economic diversification is likely to be necessary in a post-hydrocarbon era. For many MENA countries, economic development over the last 80 years has been dominated by the hydrocarbon export industry, with only limited inter-regional trade. This lack of networked economic interdependence remains a structural weakness for the region, and could constitute a major challenge as hydrocarbon sources become less productive. Some countries are, however, already investing in a post-hydrocarbon economic model. The UAE, for example, currently generates 63% of its income from commerce and tourism.[10] Alternative energy resources may reduce the region's reliance on hydrocarbons. Out to 2045, solar power may offer some opportunity to secure sustainable energy for the region. Morocco is investing significantly in solar power and Saudi Arabia has announced ambitious plans to invest some US$ 100 billion in a project designed to produce one third of its energy via solar power by 2032.[11] However, building productive solar power infrastructure across the region is challenging. Desert conditions which create an abundance of dust and a lack of water are two major obstacles that increase costs and may make solar energy prohibitively expensive for most of the less wealthy MENA countries. Lack of water is particularly problematic, as MENA is the driest and most water-scarce region in the world – the vast majority of people in North Africa survive on less than 100 mm of average annual rainfall. However, breakthroughs in solar power technology, such as photo-voltaic cells, do not use water to convert the sun's rays to electricity. If large-scale prototypes prove successful, the potential rewards are massive. Egypt, Jordan, Saudi Arabia and Turkey are all investing heavily in nuclear technology and it is likely to be an attractive alternative for many. The nuclear industry estimates that new-build contracts in the region will have passed US$ 200 billion by 2020, suggesting that by 2045 the region will have significantly increased amounts of fissile material and nuclear expertise.[12]

Fuel, food and electricity subsidies may continue to impede economic development, with the International Monetary Fund estimating that governments in the Middle East spent US$ 212 billion on fuel and food subsidies in 2011.[13] North African governments also often use state subsidies to reduce food and energy prices as a way of artificially controlling potential instability. High spending of this kind arguably threatens economic development. In the oil-producing countries in particular, subsidies have insulated producers from the need to cultivate larger markets, stifling growth. The situation is made worse because most beneficiaries are the wealthy – subsidies therefore increase the gap between rich and poor. Changing the status quo may prove difficult, due to resistance from interested parties who see subsidies as a right. In already fragile countries with poor governance, it could be very difficult for subsidies to be reduced over the next 30 years.

9 Parthasarathy, G. (2011), 'India-Middle East Relations' available at http://asianaffairs.in/february2011/india-middle-east-relations.html

10 Government Office for Science (2013), 'After the Oil: The Future of the Middle East', available at http://www.sigmascan.org/Live/Issue/ViewIssue/491/4/after-the-oil-the-future-of-the-middle-east/

11 Marc, R. and Mahdi, W. (2012), 'Saudi Arabia Plans $109 Billion Boost for Solar Power', available at http://www.bloomberg.com/news/2012-05-10/saudi-arabia-plans-109-billion-boost-for-solar-power.html

12 NuclearEnergyInsider.com (2013), 'Nuclear Construction Conference, MENA', available at http://www.nuclearenergyinsider.com/mena

13 International Monetary Fund (2012), 'Costly Middle East Subsidies Need Better Targeting', available at http://www.imf.org/external/pubs/ft/survey/so/2012/car051412b.htm

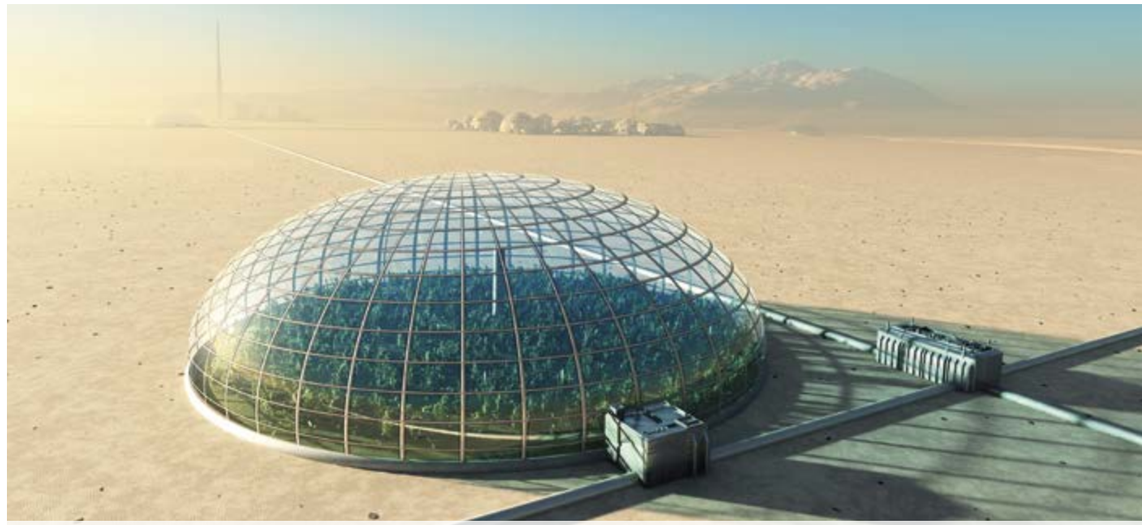
Climate, water and agriculture

The region will almost certainly be characterised by rising temperatures and hot extremes, with average annual surface temperatures projected to increase across North Africa and the northern areas of the Middle East by approximately 1.2 times more than the global average. Global drying could lead to a general increase in the size of deserts, such as the Sahara. Annual average rainfall will probably reduce, with a shift to more intense drought events which could negatively impact freshwater availability. These climate and weather factors, coupled with potentially changing pest and disease distribution, could negatively impact crop yields, particularly in the North African region. Rising sea levels will almost certainly increase the exposure of many coastal communities to flooding, with almost the entire coast of North Africa being vulnerable, due to levels of development and rapid population growth. With large populous cities, Egypt has been identified as having important centres at risk of future coastal flooding.

Education

Many MENA countries have invested heavily in education over the last half of the century. Gains have been made across the region in the education sector, with more equitable access to education being established. Gender disparity in education has reduced (but certainly not disappeared) and this has contributed towards a significant decline in birth rates and infant mortality, as well as increased life expectancy. Most children across the region now attend primary school, and rates of secondary and university education match those of countries in other regions at comparable levels of development. However, funding for education has not delivered significant results for MENA in terms of improving skills.[14] Patronage, using often

14 Badr, M. *et al.* (2012), 'Determinants of Educational Attainment in MENA', available at http://www.nottingham.ac.uk/credit/documents/papers/12-03.pdf



Agricultural productivity will be challenging, particularly in Northern Africa

out-dated or heavily religious syllabuses, and a reliance on rote-learning, have all had a negative affect on the region's ability to turn bright students into productive and skilled workers. Many of the region's education systems are unable to provide pupils with the necessary tools to transition successfully from school to work. This often drives parental decisions to remove children from education at an early stage in favour of seeking work for the child. Although there is some recognition of the need to reform education, it is likely that, until broader political and social reforms take hold in MENA, education will continue to suffer over the next 30 years.

Religion

Out to 2045, Sunni and Shia relations will almost certainly continue to cause significant friction in the Middle East. Tensions between Shiite Iran and the Sunni Gulf Cooperation Council (GCC) are likely to remain high. However, not all Shia movements will necessarily be pro-Iranian and not every Salafi (hard-line Sunni) movement will be strongly influenced by Saudi Arabia.[15] Indeed, there are significant Shiite minorities in GCC countries, as well as a growing Salafi movement in Iran. Sectarian tensions also reflect socio-economic disparities and are likely to escalate if governments do not address these fundamental issues. For example, Bahrain and Saudi Arabia, where economic inequality between Sunni and Shia is greatest, are more likely to see tensions rise than other countries in the region. Satellite television channels and social media are also likely to play an increasing role in spreading sectarian mistrust.[16] Over the next 30 years, growing tensions are also likely *within* Sunni and Shiite communities. Sunni Islam is particularly likely to become increasingly factionalised. As Salafist groups grow in prominence around the world, a backlash may emerge from moderate Sunnis. Correspondingly, Shiite Islam contains a number of internal divisions.

15 Chatham House (2012), 'Identities and Islamisms in the GCC: Future Trends in the GCC Workshop Summary', available at http://www.chathamhouse.org/sites/default/files/public/Research/Middle%20East/0512gcc_summary.pdf

16 *Ibid.*

Jerusalem, Western Wall and The Dome of The Rock. A manifestation of the proximity of religion

Terrorism

Social, economic, religious and political justifications for terrorism are likely to continue to be used by many groups within the region. Most terrorist groups in MENA are likely to continue to target Israel, western interests in the region and secular governments, with many acting in the name of Islam and following Islamic fundamentalist principles. Most terrorists are highly likely to remain focussed on attacks within the region, although Al-Qaida and affiliated groups are likely to continue to target western interests out to 2045. China is already experiencing some threat to its overseas interests within MENA, and may increase its activity in the region - which could lead to a corresponding rise in the terrorist threat to China.[17]

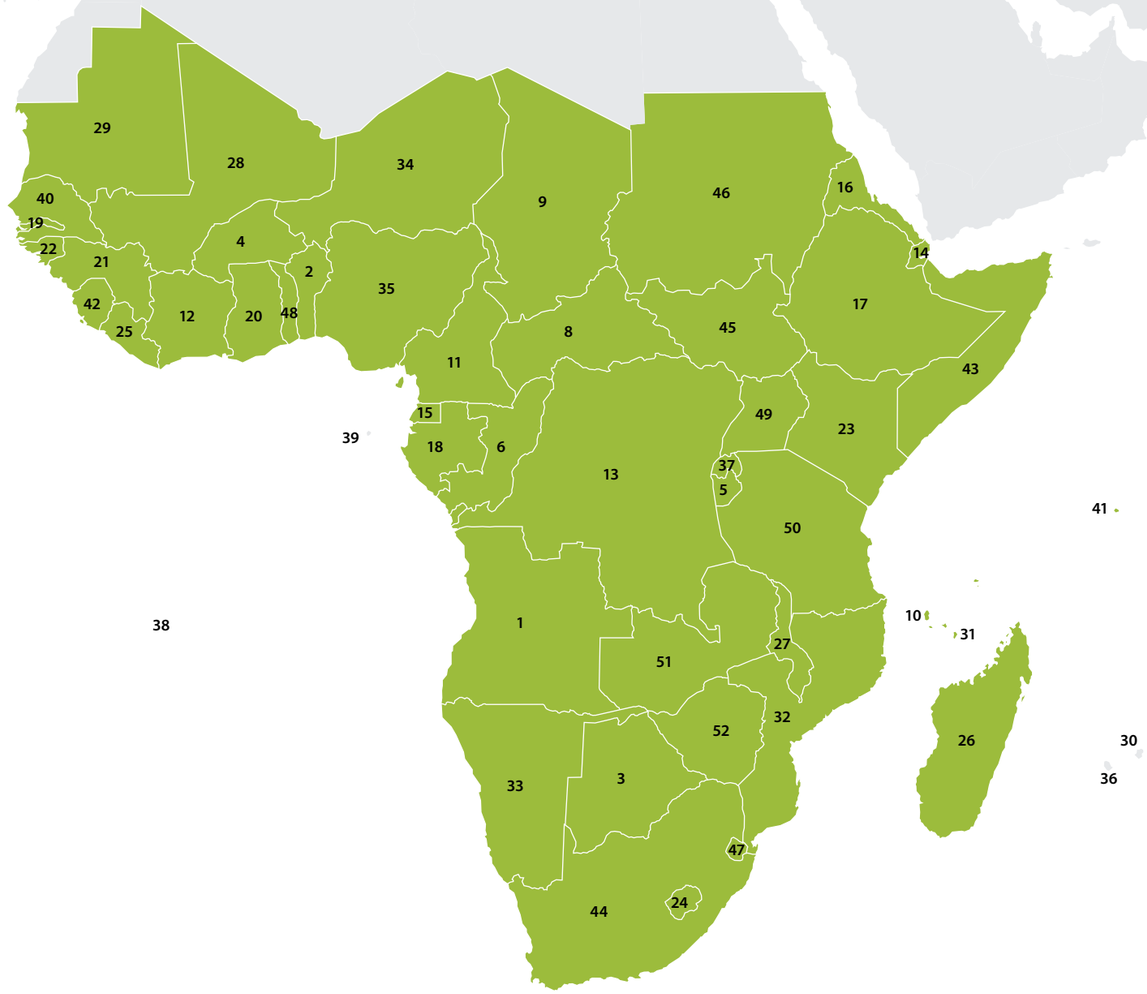
17 Zhu, W. (2011), 'Middle East Terrorism, Global Governance and China's Anti-terror Policy', available at http://mideast.shisu.edu.cn/picture/article/33/81/10/ca7475ef4594a8e57aaaaf20a6e7/ffa30577-f3be-4895-aac3-f29fa2ac421b.pdf

Defence and security implications

- MENA is highly likely to remain a volatile region over the next 30 years and the possibility of major regional conflict cannot be ruled out. The possible thawing of relations between Iran and the US could have significant implications for regional security.
- Socio-economic factors, including disparity in wealth, gender inequality and poor education, are likely to be the underlying causes of much of the unrest and sometimes violent conflict within MENA.
- Identity politics in the region, particularly sectarianism, are likely to continue to be used as a mobilising factor in conflict.
- Internal terrorist threats are likely to continue, as are attacks on other nations from groups based in the region. Although Al-Qaida has been damaged in recent years, Islamic fundamentalism will almost certainly continue to fuel terrorist networks out to 2045.

"Most terrorist groups in MENA are likely to continue to [operate], with many acting in the name of Islam."

1 Angola
2 Benin
3 Botswana
4 Burkina Faso
5 Burundi
6 Cameroon
7 Cape Verde
8 Central African Republic
9 Chad
10 Comoros
11 Congo
12 Côte d'Ivoire
13 Democratic Republic of the Congo
14 Djibouti
15 Equatorial Guinea
16 Eritrea
17 Ethiopia
18 Gabon
19 Gambia
20 Ghana
21 Guinea
22 Guinea-Bissau
23 Kenya
24 Lesotho
25 Liberia
26 Madagascar
27 Malawi
28 Mali
29 Mauritania
30 Mauritius
31 Mayotte
32 Mozambique
33 Namibia
34 Niger
35 Nigeria
36 Réunion
37 Rwanda
38 Saint Helena
39 Sao Tome and Principe
40 Senegal
41 Seychelles
42 Sierra Leone
43 Somalia
44 South Africa
45 South Sudan
46 Sudan
47 Swaziland
48 Togo
49 Uganda
50 United Republic of Tanzania
51 Zambia
52 Zimbabwe



Sub-Saharan Africa

Sub-Saharan Africa will almost certainly remain a region of significant political and economic differences by 2045 but overall the region's economy should grow – possibly rapidly. However, economic performance is likely to vary sharply from country to country, with a lack of infrastructure and political instability likely to continue to provide some of the biggest challenges to sustained growth. The region is likely to see the fastest rise in population growth of anywhere in the world, with some countries' populations more than doubling by 2045. Governance in the region is likely to improve and the current trend towards representative government is likely to continue, although this will probably be resisted by some authoritarian regimes, possibly leading to violence. The risk of state-on-state conflict is likely to reduce but will almost certainly remain a concern. By contrast, the threat from intra-state conflict and from terrorism is likely to endure and could worsen. The African Union's ability to deal with crises is likely to improve, but it will probably still require international assistance for more demanding situations. Technology is likely to facilitate links between different parts of the region and with the wider world, thereby increasing economic productivity and improving governance. If current trends continue, most people in the region are likely to have access to the Internet by 2045. Climate change is likely to have a severe impact on some parts of sub-Saharan Africa, with agriculture particularly badly affected. The region is likely to continue to face significant rates of infection from communicable diseases such as HIV/AIDS and malaria. But it is conditions such as diabetes and cancer that are likely to pose the greater health threat by 2045.

Demographics

Today, 877 million people live in sub-Saharan Africa. This is likely to double by 2045, meaning that around 20% of the world's total population could live in the region. Sub-Saharan Africa's working-age population is expected to exceed that of China by 2030 and India by 2035.[1] Correctly harnessed, this could provide a significant demographic dividend. However, this rapid population growth is likely to jeopardise social and economic development, particularly in the most vulnerable countries. With the proportion of those in the 15-25 age-group higher in sub-Saharan Africa than anywhere else in the world, young people are likely to be under- or unemployed and hence disaffected, driving instability. For example, Nigeria currently sees four million young people join the workforce each year, but only a small proportion of them find paid work.[2] In sub-Saharan Africa as a whole, official figures from 2012 put youth unemployment at 11.8% – double the rate for adults. Much of this population growth is likely to occur in urban areas, with the populations of African cities growing by an estimated 15-18 million people each year.[3] Over the next 20 years, city populations in the region are likely to grow 45% faster than

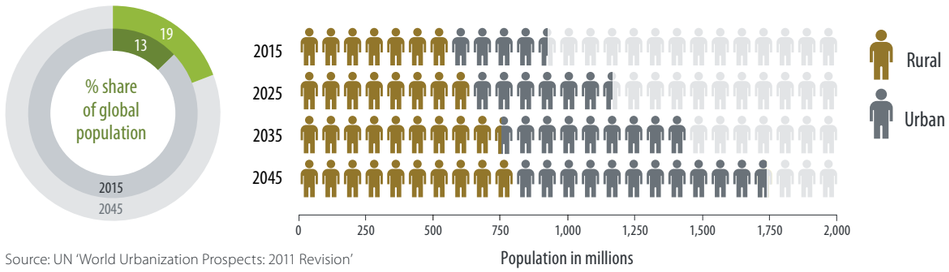
"Sub-Saharan Africa's working-age population is expected to exceed that of China by 2030 and India by 2035."

1 McKinsey Global Institute (2012), 'Africa at Work: Job Creation and Inclusive Growth'

2 High Level Panel on Fragile States (2014), 'Ending Conflict and Building Peace in Africa: A Call to Action'

3 *Ibid.*

A growing population in both rural and urban environments



Source: UN 'World Urbanization Prospects: 2011 Revision'

in rural areas, with 60% of people in Africa likely to live in cities by 2050.[4] Most sub-Saharan cities, though, are likely to struggle to provide basic services, with an estimated 100 million Africans – around 10% of the region's projected total population – living in slums by 2020.[5]

Governance

The political picture within sub-Saharan Africa will almost certainly continue to vary from country to country by 2045, but if current trends continue, there is likely to be a decrease in the overall number of coups. Between 1960 and 2000, there were approximately 20 successful coups each decade in the region, but this fell to just six in 2000-2010. (Successful coups took place in the Central African Republic, Guinea-Bissau, Mauritania (twice), Guinea and Madagascar.) A number of countries in sub-Saharan Africa now have democratically elected governments. This shift towards representative government is likely to continue, driven by improved education, higher income and better access, via technology, to information and different points of view.[6] Demand and support for greater representation is likely to become widespread among the general public, mobilising an increasingly politically active and outspoken population. However, the path towards democracy is unlikely to be smooth. Although multi-party elections will almost certainly become the norm in most sub-Saharan countries, they will probably vary in quality. Flawed democracies are still likely to be prevalent in 2045, with some countries subject to authoritarian governments. Demands for democratic elections could become violent, particularly in areas where democracy is not entrenched.

"There has been a steady decline in rates of state-on-state conflict in the region as a whole and this trend is likely to continue."

Corruption is likely to decline in some parts of the region while enduring in others. Currently, three of the world's ten most corrupt countries are found in sub-Saharan Africa (Somalia, Sudan and South Sudan), while only three are among the 50 least corrupt countries (Botswana, Cape Verde and Rwanda).[7] Poverty, weak political institutions and poorly developed institutional checks and balances will probably continue to drive and allow corruption in some parts of the region. However, this is likely to be mitigated to some extent by: deeper involvement of civil groups; strengthening the judiciary; more transparency (facilitated in large part by increasing information and communication technology); and increasing education and corruption-awareness programmes. This could lead to a decline in overall levels of corruption (as perceived today) by 2045.

Terrorism and conflict

There has been a steady decline in rates of state-on-state conflict in the region as a whole and this trend is likely to continue out to 2045 – although some areas will remain contested. Intra-state conflict will almost certainly endure, and fragmentation of some countries remains possible, perhaps likely. The risks of instability and violence are unlikely to disappear (and may even increase in some areas) due to factors such as dramatic population growth, unfulfilled expectations, unemployment, radicalising ideologies, widening inequalities and differences in access to resources. These factors may also increase the risk of terrorism out to 2045. A number of more positive trends, however, may provide a measure of mitigation, such as stronger civil societies, economic growth, greater access to education and the growing empowerment of women.[8] Indeed, the number of women entering politics has increased – for example, the number of women members of the South African Parliament has more than doubled since 1994. Also, the capacity of African governments and regional organisations, particularly the African Union, to deal with security challenges is likely to increase – although the more demanding security challenges are still likely to require international assistance.

Resources

Sub-Saharan Africa is likely to continue to be resource-rich, with new oil and gas discoveries likely to be made, potentially helping to satisfy the world's rising demand for hydrocarbons. While this revenue is likely to boost the region's economies, it may exacerbate existing inequalities by concentrating wealth in the hands of a small number of people. Oil and gas production is likely to grow faster in sub-Saharan Africa than in other regions, attracting significant foreign investment.[9] China is highly likely to continue to be involved in the region, but could become less welcome if it is viewed as being exploitative rather than as an investor. With this increasing potential wealth, however, comes a corresponding increase in the potential for violence. Between 2010 and 2011, friction over resources accounted for approximately 35% of all conflicts in sub-Saharan Africa – and this trend is likely to continue.[10] By 2045, dramatic population growth and the increasing threat from climate change are likely to increase competition for

A resource rich region will attract foreign investment

4 High Level Panel on Fragile States, *op. cit.*

5 *Ibid.*

6 Cillers, J., Hughes, B. and Moyer, J. (2011), 'African Futures 2050'

7 Transparency International (2013), 'Corruption Perception Index 2013', available at http://www.transparency.org/cpi2013/results

8 Cillers, J. and Schünemann, J. (2013), 'The Future of Intrastate Conflict in Africa: More Violence or Greater Peace?'

9 Verma, Raj (2012), 'Is Africa the New Persian Gulf? Not Yet'

10 Heidelberg Institute for International Conflict Research (2012), 'Conflict Barometer 2012'

Falling crop yields may be alleviated by improvements in science and technology

"Rising sea levels will almost certainly increase the risk of flooding for ecosystems and coastal communities."

food, water and energy – these factors may also act as catalysts for further violence and instability, particularly in the most fragile countries.[11] Water scarcity could be a key driver of conflict – water basins which cross national boundaries account for 90% of Africa's surface water, with the Congo Basin alone spanning ten countries.[12]

Climate

The sub-Saharan economy will almost certainly continue to rely on climate-sensitive activities out to 2045. Average annual temperatures are projected to increase, as are instances of heatwaves. Annual average rainfall is also likely to increase over the tropical regions (particularly in east Africa) but decrease over the sub-tropical regions. The variability of rainfall is likely to change, with both intense rainfall and drought events becoming more frequent. The south of the region is likely to be particularly at risk of severe droughts. Rising sea levels will almost certainly increase the risk of flooding for ecosystems (such as mangroves) and coastal communities (including a number of cities) with Mozambique and small island states particularly at risk.

Agriculture and fisheries

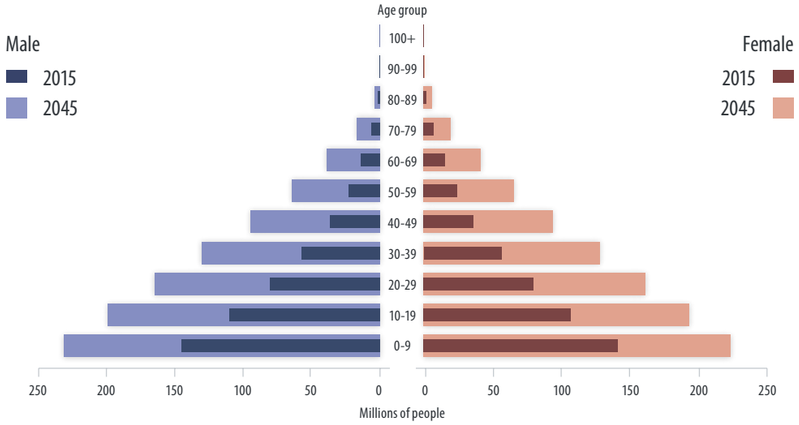
Many crops in the region are already grown close to their limits of heat tolerance and 95% of sub-Saharan Africa's agriculture is rain-fed. Overall crop yields are expected to decline, and while improvements in science and technology have the potential to alleviate these challenges, the region could face decreasing productivity and increasing food prices. Declines are projected for key crops including wheat, maize, sorghum, millet and groundnut. This is likely to impact productivity in a number of countries, particularly South Africa, Zimbabwe and those in the east.

11 Cillers and Schünemann, *op. cit.*

12 High Level Panel on Fragile States, *op. cit.*

An ageing population

Population by ten-year age group and sex



Source: UN (2012), 'World Population Prospects: The 2012 Revision'

Ocean acidification and temperature changes are also likely to adversely affect marine ecosystems and fishing industries.

Technology

The growth of information and communication technology within sub-Saharan Africa, although uneven, is likely to drive change and improve the region's integration with the rest of the world, including via diaspora communities. Internet connectivity is likely to continue to improve and, if current trends continue, the majority of people should have access to the Internet and mobile communications technology by 2045. As communication gets easier, people are likely to be able to monitor their governments more readily and press for improvements.[13] Governments will probably find it harder to control or restrict the flow of information and to hide abuses of power from the public.

Health

Mortality levels in most sub-Saharan countries have decreased and are likely to continue to do so out to 2045. Of particular note are infant and child mortality levels, which have declined by approximately 50% between the 1980s and the present day.[14] These decreases are primarily due to sanitation programmes, vaccination campaigns and providing nutritional supplements. Although the number of AIDS-related deaths has noticeably decreased throughout the region, with significant progress in reducing mother-to-child transmission of HIV,[15] rates of infection are still extremely high – over 4% of adults currently live with the disease.[16] Unless an affordable cure is found, the disease is still likely to be prevalent in 2045. The same is true for malaria, which caused an estimated 627,000 deaths worldwide in 2012, mostly among African children.[17] Changes in temperature and rainfall could impact the geographic distribution of malaria, causing areas of contraction as well as expansion. However, socio-economic factors are likely to continue to play a significant role in incidence rates. Sub-Saharan Africa is also likely to see a rise in non-communicable diseases such

13 Center for Strategic and International Studies (2011), 'Assessing Risks to Stability in Sub-Saharan Africa'

14 JICA Research Institute (2013), 'Development Challenges in Africa Towards 2050'

15 UNAIDS (2012), 'Regional Fact Sheet'

16 World Health Organisation (2011), 'Global Health Observatory: HIV/AIDS', available at http://www.who.int/gho/hiv/en/

17 World Health Organisation (2013), 'Malaria Fact Sheet No. 94', available at http://www.who.int/mediacentre/factsheets/fs094/en/index.html

"As communication gets easier, people are likely to be able to monitor their governments more readily and press for improvements."

as hypertension, heart disease and cancer.[18] There is an increasing trend in hospitalisation and mortality due to such diseases, which are likely to account for more than 20% of the disease burden by 2030. By 2045, the number of deaths due to non-communicable diseases in Africa is likely to exceed the combined deaths from communicable disease, nutritional deficits and maternal and prenatal deaths.[19] Health services in sub-Saharan Africa are currently under-resourced and struggle to meet the demand for services. The region has 14% of the world's population and 24% of the world's diseases, yet it only has 1.3% of global health workers.[20]

"Some projections see [the region] achieving the highest rate of global economic growth between 2030 and 2050."

Economic growth

Economic inequalities between countries are likely to continue and potentially increase out to 2045.[21] Some sub-Saharan countries have developed diverse economies which are likely to reduce their vulnerability to external shocks and enable them to achieve long-term growth. Other countries lack strong, stable governments and institutions – this is likely to hinder their ability to build a better business environment in the future. Although there is cautious optimism about the region's potential to compete in global manufacturing,[22] unless skills shortages and infrastructure challenges are addressed, only a few sub-Saharan countries are likely to be able to compete with countries such as Vietnam or Indonesia by 2045. Although Africa is expected to continue to be the world's poorest region, some projections see it achieving the highest rate of global economic growth between 2030 and 2050.[23]

18 World Bank (2008), 'The Business of Health in Africa', available at http://www.unido.org/fileadmin/user_media/Services/PSD/BEP/IFC_HealthinAfrica_Final.pdf

19 World Health Organisation (2013), 'Fact Sheet: Non-Communicable Diseases', available at http://www.who.int/mediacentre/factsheets/fs355/en/

20 IRIN News (2008), 'Africa: Climate Change Linked to Spread of Disease'

21 McKinsey Global Institute (2010), 'Lions on the Move: the Progress and Potential of African Economies'

22 Dinh, H. T. (2012), 'Opinion: Could Africa Be World's Next Manufacturing Hub?', available at http://edition.cnn.com/2012/06/15/opinion/africa-manufacturing-hub/

23 OECD (2012), 'Environmental Outlook to 2050'

Defence and security implications

- The risk of state-on-state conflict is likely to reduce overall, although instability and violence will almost certainly continue out to 2045, possibly increasing in some areas.
- Terrorist organisations are likely to continue to pose a threat to peace and security, driven by youth unemployment, dissatisfaction with governing regimes and the mis-management of natural resources.
- The African Union's ability to handle crises is likely to improve, although it will probably still require support from the international community to deal with more demanding situations.
- The combined challenge of an increased population, demands on resources and the effects of climate change (particularly drought) on food and water supplies are likely to lead to tension, which could result in conflict.
- The urban population is likely to increase significantly and many more cities are likely to be located on or near the coast. Rising sea-levels are likely to lead to humanitarian disasters that will probably need an international response.

Central Asia

Despite the divergent paths taken by the five Central Asian republics since their independence from the Soviet Union, each remains vulnerable to social and economic risks. These potential problems stem from internal threats caused by weak infrastructure and institutions, as well as their relations with external actors. As a result, the region is susceptible to ethnic conflict, sudden political transitions, economic shocks, food insecurity and natural disasters – all potentially posing strategic threats beyond Central Asia to the rest of the world.

External influences

Compared to the other Central Asian countries, Kazakhstan has greater capability and scope to pursue an independent foreign and economic agenda. The other four republics are likely to be the subjects of competing interest from powers outside the region.[1] As its own large reserves in the Arctic become more accessible, Russia may no longer see an overriding need to maintain specific influence linked to Central Asia's oil and gas supplies. Nevertheless, Russia is likely to continue to seek to be the dominant external actor in the region, aiming to prevent other foreign powers from attaining a high degree of political or military influence.[2] China is likely to continue to invest in Central Asian agriculture, energy reserves and associated infrastructure, looking for extra ways to link the countries in the region to each other and to itself. This is likely to be welcomed overall, but some in Central Asia may be concerned about economic competition caused by the influx of Chinese goods into local markets. Among the South Asian countries, India and Pakistan (as well as Afghanistan) have most to gain from energy and trade relations with Central Asia, but – with the exception of Pakistani-Turkmen gas cooperation – are unlikely to be as influential as China in the region. The region's largest trading partner, the EU, is likely to remain influential in 2045, as is the US. Although all the major regional actors have an interest in Central Asia, none appears to have a strategy of territorial expansion into the region or of becoming directly involved in security issues.

Internal threats

All the Central Asian republics are vulnerable to significant political and social threats that, in turn, pose risks to the region's security.[3] Of the five, Kazakhstan is the most stable. However, the eventual departure of its long-standing President will almost certainly give rise to some jockeying for position. Kazakhstan's institutions are likely to be sufficiently developed to prevent subsequent outbreaks of widespread violence or separatism. Kazakhstan also has the greatest political and economic independence from Russia, arguably making it the most important Central Asian country.[4]

"Kazakhstan has the greatest political and economic independence from Russia, making it the most important Central Asian country."

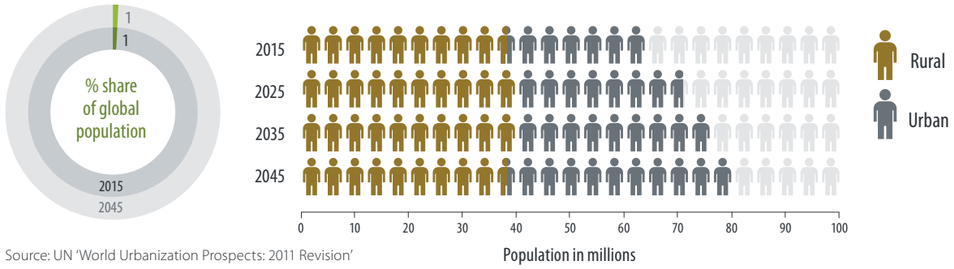
1 Oxford Analytica (2013), 'South and Central Asia Workshop: Strategic Trends out to 2045. Summary report produced for DCDC'

2 Chatham House (2012), 'The Long Goodbye: Waning Russian Influence in the South Caucasus and Central Asia', available at http://www.chathamhouse.org/sites/default/files/public/Research/Russia%20and%20Eurasia/0612bp_nixey.pdf

3 Oxford Analytica, *op. cit.*

4 Chatham House, *op. cit.*

A growing population living in the urban environment



Source: UN 'World Urbanization Prospects: 2011 Revision'

By contrast, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan have comparatively weak government institutions and relatively unitary political hierarchies (with the partial exception of Kyrgyzstan, which is demonstrating trends towards greater pluralism). Like Kazakhstan, Uzbekistan may also face challenges with political stability due to an aging President and no clear successors. Out to 2045, Southern Kyrgyzstan is likely to remain a hotbed of inter-ethnic violence between ethnic Kyrgyz and Uzbek communities, arising out of each community's perceptions of unequal opportunities, historic grievances and the central government's lack of control over local security forces. A porous border with Afghanistan is likely to continue to make Tajikistan vulnerable to developments in the north of that country, particularly if historic conflicts resurface between Tajikistan's government forces and Islamist insurgents. In Uzbekistan, persistent poverty and inappropriate distribution of basic resources (such as land and water) will probably be long-term drivers of instability.

"All five Central Asian countries face parallel risks to their water security as a consequence of cross-border disputes."

Religion

Islamist movements stand almost no chance of overpowering state institutions or gathering substantial support in urban areas.[5] Nevertheless, the overall manner in which the governments of the region have sought to combat extremism has exacerbated the problem. It is also likely to remain a long-term (if low-level) threat to stability. Out to 2045, continued socio-economic adversity and growing animosity towards an overbearing, monopolistic state are likely to increase the number of instances of instability across Central Asia. Social discontent may result in support for underground religious movements rather than opposition parties, which are expected to remain weak.

Resources

Fluctuations in food prices and low levels of self-sufficiency will almost certainly continue to test the ability of Central Asian countries to manage their food supply. Kyrgyzstan and Tajikistan currently import significant proportions (over 30%) of their food supplies and remain the most vulnerable to price fluctuations and supply disruptions. In Uzbekistan and parts of Tajikistan, state policies of cotton cultivation have dramatically reduced the amount of land available for arable farming. Such policies are likely to remain in place for the foreseeable future given how important cotton is to both countries' economies. All five Central Asian countries also face parallel risks to their water security as a consequence of cross-border disputes over the Amu Darya and Syr Darya rivers and the Caspian Sea.

Climate

The region is characterised by a generally high altitude, arid and semi-arid conditions with warm summers and cold winters, with seasonal rainfall affecting water availability and flooding. Average annual temperatures are likely to increase by around 1.5°C by the middle of the century. Existing low water availability in the west of the region is likely to worsen. Heatwaves will probably increase in frequency and magnitude, while extreme cold events are likely to decrease across the region.

5 Oxford Analytica, *op. cit.*

Natural disasters

All five Central Asian countries are, and will almost certainly remain, prone to severe earthquakes and other natural disasters.[6] The most seismically active areas are often the most densely populated, among them the Osh region in Kyrgyzstan and the Ferghana Valley, which includes parts of Kyrgyzstan, Tajikistan and Uzbekistan and is home to more than 11 million people (nearly 20% of the region's population).[7] Institutional weakness and budgetary constraints leave populations in Central Asia particularly vulnerable to natural disasters. The only exception is Kazakhstan, which has initiated long-term reform efforts and dedicated financial resources to develop risk management capabilities. By contrast, Kyrgyzstan has repeatedly failed to take into account the warnings of seismologists, and more than 60% of the population live in housing that is not able to withstand the strong earthquakes that the region is likely to continue to experience.[8]

Economic vulnerability

Unemployment and poor resource availability mean that many people in the region are likely to continue to migrate to find work. There have been large population movements across Central Asia since independence, both within and between countries, and these increasingly reflect economic considerations. Together with Russia, Kazakhstan has become the preferred destination for immigrants from the poorer countries of Central Asia, while Tajikistan, Uzbekistan and Kyrgyzstan have become increasingly dependent on money sent home by emigrants (which currently accounts for 50% of GDP in Tajikistan, 40%

6 Oxford Analytica, *op. cit.*

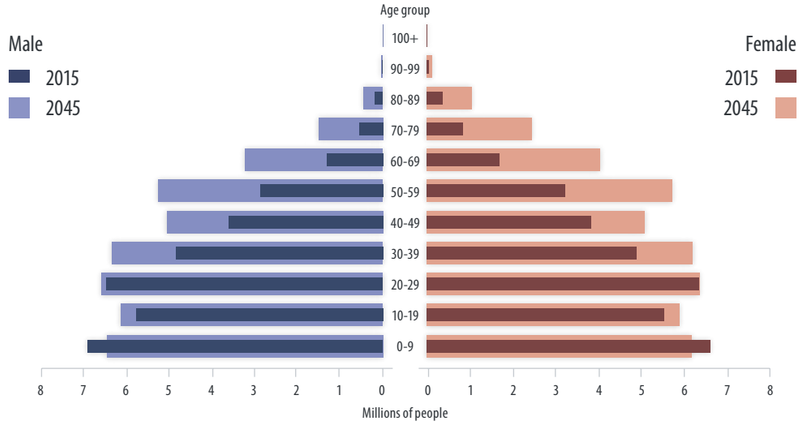
7 Asian Development Bank (2010), 'Central Asia Atlas of Natural Resources'

8 Swiss Agency for Development and Cooperation (2008), 'Kyrgyzstan Earthquake Safety Initiative Project', available at http://www.swiss-cooperation.admin.ch/centralasia/en/Home/Activities_in_Kyrgyzstan/COMPLETED_PROJECTS/Kyrgyzstan_Earthquake_Safety_Initiative

A mosque in Khiva, Uzbekistan

An ageing population

Population by ten-year age group and sex



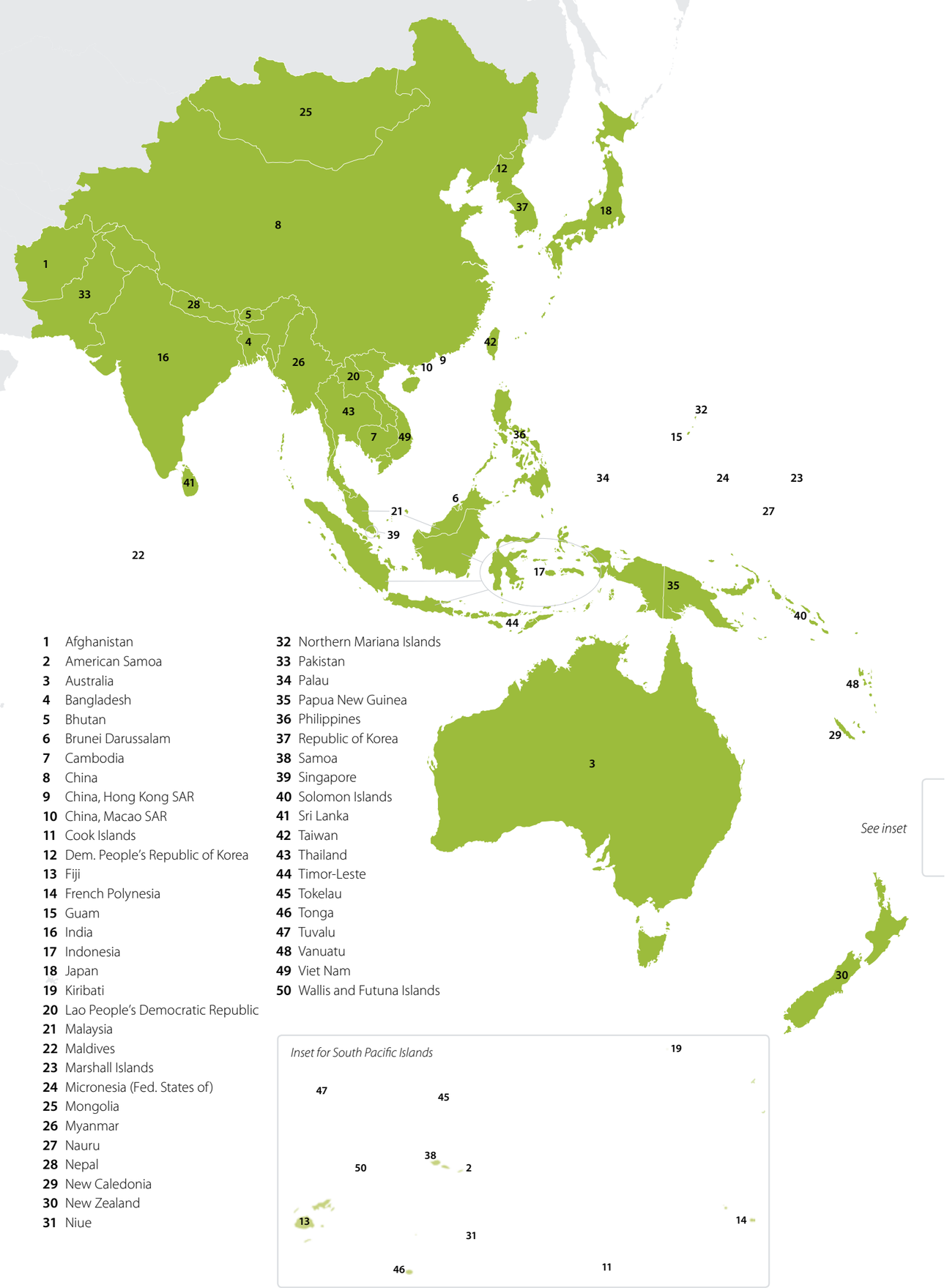
Source: UN (2012), 'World Population Prospects: The 2012 Revision'

in Kyrgyzstan, and 10% in Uzbekistan).[9] The viability of this development model depends on external circumstances, and particularly on the continued demand for imported labour in Russia and, to a lesser extent, Kazakhstan. The labour-exporting countries are, therefore, extremely vulnerable to an economic downturn in the host economies or to the imposition of migration restrictions. Such limits are likely to be put in place by 2045 due to Russia's economic difficulties and associated anti-immigrant violence. At the same time, Uzbek and Turkmen dependence on oil and gas exports is likely to continue to make both countries vulnerable to downturns in demand outside the region and to reducing levels of supply. Out to 2045, Tajikistan, Kyrgyzstan, Uzbekistan and Turkmenistan are therefore likely to be at risk of instability from economic hardship.

9 Oxford Analytica, *op. cit.*

Defence and security implications

- Although all the major regional actors have an interest in Central Asia, none appears to have a strategy of territorial expansion into the region or of becoming directly involved in security issues.
- The primary triggers of instability in Central Asia remain rooted in the internal politics of each country. Countries in the region are likely to remain vulnerable to significant political and social threats that, in turn, pose risks to the region's security.



1 Afghanistan
2 American Samoa
3 Australia
4 Bangladesh
5 Bhutan
6 Brunei Darussalam
7 Cambodia
8 China
9 China, Hong Kong SAR
10 China, Macao SAR
11 Cook Islands
12 Dem. People's Republic of Korea
13 Fiji
14 French Polynesia
15 Guam
16 India
17 Indonesia
18 Japan
19 Kiribati
20 Lao People's Democratic Republic
21 Malaysia
22 Maldives
23 Marshall Islands
24 Micronesia (Fed. States of)
25 Mongolia
26 Myanmar
27 Nauru
28 Nepal
29 New Caledonia
30 New Zealand
31 Niue
32 Northern Mariana Islands
33 Pakistan
34 Palau
35 Papua New Guinea
36 Philippines
37 Republic of Korea
38 Samoa
39 Singapore
40 Solomon Islands
41 Sri Lanka
42 Taiwan
43 Thailand
44 Timor-Leste
45 Tokelau
46 Tonga
47 Tuvalu
48 Vanuatu
49 Viet Nam
50 Wallis and Futuna Islands

South & East Asia and Oceania

China and India will almost certainly continue to be the dominant powers in the region by 2045, with their economies ensuring that South & East Asia makes the biggest contribution to the world's GDP. Japan is likely to continue to have the region's third-largest economy. In Oceania, Australia will almost inevitably remain the dominant power and have the largest economy. South & East Asia and Oceania are likely to continue to contain over 50% of the world's population by 2045, presenting both benefits and challenges. China and India are likely to continue to devote considerable resources into ensuring economic growth and both countries are likely to continue to seek a strong economic relationship with the US. The way that China and India manage their societies' demands and their internal methods of governance will be important to the region's development. Both China and the US are likely to become increasingly dependent on the global economy for their long-term stability, prosperity and security.

Demography

The average age of China's population is likely to increase from 34 in 2011, to 46 in 2045, with some projections seeing China's workforce shrinking by 2045 as a result of population aging.[1] This could lead to China becoming one of the first countries to age before it gets wealthy.[2] The populations of South Korea, Japan and parts of Oceania will almost certainly become significantly older. Countries with younger age profiles and larger populations, such as Bangladesh, India, Indonesia, Pakistan and the Philippines are likely to enjoy the economic benefits of productive, and relatively cheap, manpower. However, all countries will probably need to develop adequate social policies, to ensure that large-scale inequality and poor education do not generate social problems that lead to instability. Furthermore, many South & East Asian countries have significantly more men than women. For example, China is likely to have around 48 million more men than women by 2045. This could lead to social challenges, particularly as male-dominated societies tend to be more authoritarian and more prone to violence.[3] Urbanisation will almost certainly continue at a rapid rate, with many cities located in coastal areas vulnerable to flooding.

Economic and strategic importance

As well as containing over 50% of the world's population,[4] South & East Asia are also likely to be the greatest contributor to global GDP from 2030 onwards.[5] Its huge population could provide a vast consumer market, while

"Urbanisation will almost certainly continue at a rapid rate, with many cities located in coastal areas vulnerable to flooding."

1 OECD (2012), 'Environmental Outlook to 2050'

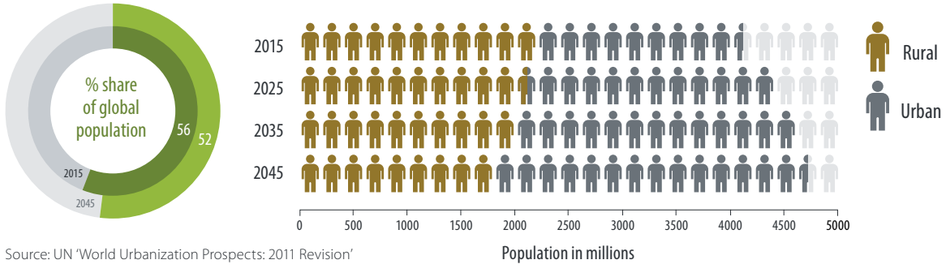
2 Goldman Sachs (2011), 'Population Growth and Ageing in the BRICs', available at http://www.goldmansachs.com/our-thinking/archive/archive-pdfs/population-growth-ageing-brics.pdf

3 Caprioli, M. and Trumbore, P. F. (2003), 'Identifying 'Rogue' States and Testing their Interstate Conflict Behavior', available at http://lib.znate.ru/docs/index-124184.html

4 UN (2012), 'World Population Prospects: The 2012 Revision', available at http://esa.un.org/wpp/unpp/panel_population.htm

5 Standard Chartered (2010), 'The Super-Cycle Report', available at https://www.sc.com/id/_documents/press-releases/en/The%20Super-cycle%20Report-12112010-final.pdf. Projections that suggest that China, India, Japan and the rest of Asia combined will contribute 47% to global GDP by 2030, as opposed to 26% from the EU and US.

A growing population living in the urban environment



Source: UN 'World Urbanization Prospects: 2011 Revision'

continued industrialisation, investment in research and improved transportation infrastructure are likely to drive economic growth and build independent capabilities across South & East Asia and beyond. For example, the further development of the Pan-Asia railway network includes a proposed rail link between China and Central Asian states as well as between China and Russia. The economic growth of China, possibly succeeded by India, will probably command particular attention over the next 30 years. Forecasts suggest that by 2045 China, the EU, India and the US will form the world's largest economies, with Japan also likely to remain an important economic power, both regionally and globally. These countries or (in the EU's case) blocs are likely to engage increasingly with each other on a host of issues ranging from defence, through to climate change and, perhaps most significantly, continued national economic and industrial development. Most countries in South & East Asia are likely to continue to enjoy strong economic growth – with Indonesia likely to be one of the world's ten largest economies by 2045. Australia will almost certainly remain the dominant economy in Oceania.

Maintaining economic growth will probably be the pressing national priority for all South & East Asian nations, but for India and China it is likely to take precedence over all matters except national sovereignty and security. An enduring aim of both countries is likely to be sustaining a stable external environment, allowing India and China to pursue domestic reforms and expand trade and investment opportunities with as many countries as possible. However, both India and China are likely to face problems such as the effects of climate change, growing populations of varying composition and challenges to their systems of government. How India and China meet these challenges is almost certain to have profound implications nationally, regionally and globally. Other South & East Asian nations, such as Indonesia, are also likely to see strong economic growth and face similar challenges, but none of them are likely to rival India or China. The Chinese Renminbi and possibly the Indian Rupee are likely to be traded internationally as reserve currencies by 2045 – assuming that both countries can undertake the necessary economic reforms to make this possible. Given the strength of the Chinese economy it is possible (though not necessarily likely) that the Renminbi could rival the US dollar as the world's principal reserve currency by 2045.[6]

"China and India are likely to attain global leadership in select technical disciplines, achieving parity with the West in a number of niche areas as soon as 2015."

Technology

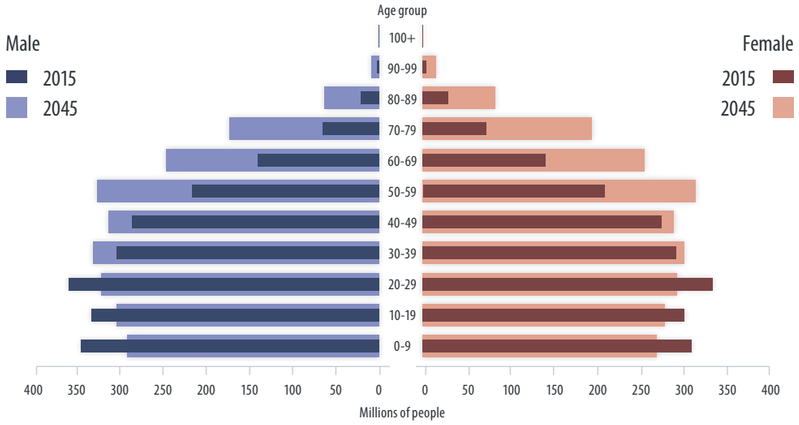
China and India are likely to attain global leadership in select technical disciplines, achieving parity with the West in a number of niche areas as soon as 2015 and more widely by 2045. Chinese companies are already filing more international patent applications than businesses in the US or Japan.[7] As South & East Asian nations become increasingly

6 Bloomberg (2011), 'China's Yuan Convertible by 2016 in Global Poll Marking Big Investor Shift', available at http://www.bloomberg.com/news/2011-05-12/china-s-yuan-convertible-by-2016-in-poll.html

7 Reuters (2011), 'China tops U.S, Japan to Become Top Patent Filer', available at http://www.reuters.com/article/2011/12/21/us-china-patents-idUSTRE7BK0LQ20111221

An ageing population

Population by ten-year age group and sex



Source: UN (2012), 'World Population Prospects: The 2012 Revision'

significant developers of technology, protecting their intellectual property from theft and infringement will probably become more important. The region's strength in technology is likely to be enhanced by continuing high levels of investment in education. South & East Asian countries have, and are projected to continue to have, higher rates of enrolment in science and technology courses than western countries – Japan, Taiwan, Malaysia, Singapore and South Korea are already highly advanced.

Energy

As their populations and economies grow, South & East Asian countries are likely to need access to more energy – and consequently, will probably seek to secure bilateral deals with other resource-rich nations around the globe. China and India are likely to lead the field in securing such agreements. For example, China is making significant investment in infrastructure, including pipelines, to bring oil and gas from Burma. China is currently the world's largest producer of greenhouse gases (although it emits less on a per-capita basis than most developed nations) but India could be a bigger emitter by 2045. However, growing demand for coal and hydrocarbons across the region is likely to increase prices which may make alternative energy sources (such as renewable and nuclear energy) more viable. Japan is a major investor in renewable energy and India, in particular, has large reserves of material that can be used to produce nuclear energy, such as thorium – a naturally occurring element.

Religion

Religious tensions throughout the region are likely to endure. Relations between religious groups will probably vary between countries, largely depending on the strength of political institutions and how well ideas of national identity and cultural pluralism are propagated. In India, sectarian violence (for example, between Hindus and Muslims) is likely to continue, although elections could ameliorate tensions – at least in some regions. In Pakistan there is a risk that permissive conditions for persecuting the Shiite minority will endure.[8] Burma has seen large-scale violence between Buddhists and Muslims which shows little sign of abating, with tens of thousands of people displaced from their homes, and hundreds of fatalities.[9] Malaysia has banned the preaching of Shiite Islam since 1996,

8 Ganguly, S. (2007), ' The Roots of Religious Violence in India, Pakistan and Bangladesh'

9 Pew Research Centre (2014), 'Religious Hostilities Reach Six-Year High', available at http://www.pewforum.org/files/2014/01/RestrictionsV-full-report.pdf

"Christians make up around 5% of China's population; the country could have the world's largest Christian community by 2030."

and anti-Shia sentiment has arguably been building throughout the 21st century, fuelled by the growth of Wahabism (a conservative Sunni faction) in Malaysia.[10] China has also seen religious tensions turn into violence, for example with an attack on Muslims by Buddhist monks in 2012, at the site of a new mosque.[11] In Indonesia, the persecution of Shiite minorities (including the burning of Shiite villages in 2012 in East Java, which led to the displacement of hundreds of people) has drawn international attention.[12] However, a peace treaty initiated by Sunni and Shiite communities in Sampang, which saw the safe return of exiled Shias, the creation of new housing and schools, and promises of reconciliation, may offer hope for future Shia-Sunni relations in Indonesia.[13]

Christianity could have a growing role in a number of countries in South & East Asia over the next 30 years. An estimated 29% of South Koreans are adherents, making Christians the largest religious group in the country.[14] China has seen a rapid rise in the numbers of Christians since the middle of the 20th century, with numbers of Protestants growing from one million in 1949 to more than 58 million by 2010.[15] Christians make up around 5% of China's population,[16] and some commentators have suggested that the country could have the world's largest Christian community by 2030.[17]

Climate

Temperatures are likely to rise across the region over the next 30 years. Average annual rainfall will almost certainly increase in most areas, with a rise in monsoon rainfall potentially leading to more flooding and reduced crop yields. Nevertheless, droughts may increase in frequency and intensity across the region, particularly in central and western Australia, southern Asia and southern China. Extreme cold events are likely to decrease across the region. High temperature extremes will probably increase in frequency and magnitude. The danger from wild fires across Australia is projected to increase, with a reduced interval between fires, as well as increased fire intensity. Fires are likely to spread faster and be harder to put out. Southern areas are identified as being at particularly high risk.

The majority of countries in the region are likely to adopt at least some measures to counter the effects of climate change. Measures adopted by China are likely to be particularly important, as it is the world's biggest emitter of greenhouse gases (although not on a per-person basis). China's system of government allows the country to implement environmental policies rapidly – for example, its recent Renewable Energy Law was drafted in less than nine months and passed with no amendments the following year. However, China's directive approach can have unintended effects – in 2009 and 2010, local governments imposed rolling power cuts to meet emission targets, even as temperatures dropped to -10°C.[18] The consequences of such measures have and could continue to result in a backlash; hence environmental policies failing in the long-term.

10 Mahavera, S. (2013), 'Ignorance, Extremist Sunnis Fuelling Anti-Shia Sentiments in Malaysia, Says Academic', available at http://www.themalaysianinsider.com/malaysia/article/ignorance-extremist-sunnis-fuelling-anti-shia-sentiments-in-malaysia-says-a

11 Pew Research Centre (2014), *op. cit.*

12 Human Rights Watch (2013), 'Indonesia: Ensure Safe Return Home of Evicted Shia Villagers', available at http://www.hrw.org/news/2013/06/30/indonesia-ensure-safe-return-home-evicted-shia-villagers

13 The Shia Post (2013), 'Indonesia: Sampang Sunni, Shia Muslims Sign Peace Treaty', available at http://en.shiapost.com/2013/09/25/indonesia-sampang-sunni-shia-muslims-signpeace-treaty/; The Jakarta Globe (2013), 'Government to Place Sampang Shiites' Future in Sunni Leaders' Hands', available at http://www.thejakartaglobe.com/news/govt-to-place-sampang-shiites-future-in-sunni-leaders-hands/

14 Pew Research Centre (2012), 'The Global Religious Landscape'

15 Phillips, T. (2014), 'China on course to become 'world's most Christian nation' within 15 years', available at http://www.telegraph.co.uk/news/worldnews/asia/china/10776023/China-on-course-to-become-worlds-most-Christian-nation-within-15-years.html; Pew Research Centre (2012), *op. cit.*

16 Pew Research Centre (2012), *op. cit.*

17 Phillips, *op. cit.*

18 Gilley, B. (2012), 'Authoritarian Environmentalism and China's Response to Climate Change', available at http://www.web.pdx.edu/~gilleyb/Gilley_AuthoritarianEnvironmentalism.pdf

Water

Increasing annual rainfall across parts of eastern Asia is likely to lead to increased river-runoff, but demand for water will probably also increase. Changes to the Asian summer monsoon may result in increased flooding, but overall rainfall in South Asia could reduce. Many people across Asia rely on glacial melt water which, due to continued melting, is likely to increase out to 2045 (but decrease beyond then). Growing populations with higher expectations, inefficient water usage, rising levels of pollution and more diversions are likely to increase the regional demand for water, which could heighten tensions over, and competition for, shared resources. South Australia is likely to become drier and the volume of water flowing in the Murray-Darling Basin (the largest river basin in the country, accounting for approximately 70% of irrigated crops and pastures) could reduce by between 10-25% by 2045. While north-eastern regions of Australia may experience moderate increases in yield, average crop yields are projected to decrease across the country.

Agriculture

The effect of climate on agriculture is almost certain to vary. Rice yields in East Asia, particularly in the Yangtze region could decrease. However, potato, rice, and winter wheat yields in other areas of China may increase. Cereal production across South & East Asia is projected to decrease, particularly in the Indo-Gangetic Plains. Severe crop failure is likely to force people to move, mostly within their country of origin, but a small proportion of the affected people (current estimates suggest around 1-2% of the population) is likely to undertake international migration.

Marine and coastal areas

A large proportion of the world's coral reefs are located in Asia and Oceania, many of which are likely to be affected by climate change, reducing biodiversity and productivity. A significant proportion of the Great Barrier Reef is projected to experience coral bleaching – adversely affecting fisheries.

Rice terraces in Longsheng, China

A changing climate threatens marine habitats such as Australia's Great Barrier Reef

Rising sea levels are also likely to increase stress on coastal habitats and cause an increase in coastal flooding. Many Asian cities are highly likely to be at risk of such flooding, including: Calcutta, Mumbai, Shanghai, Ho Chi Minh City and Bangkok. Although no major cities in Australia or New Zealand have been identified as being at high risk of flooding due to rising sea levels, a significant proportion of both countries' populations live near the coast. The impact of sea-level rise on low-lying island countries such as the Maldives and Vanuatu may lead to wholesale international migration by these small nations. Singapore will almost certainly be threatened by climate change but is likely to have sufficient resources to protect itself from catastrophic effects.

"Both India and China will probably seek to develop sizeable and technically advanced armed forces, including ocean-going navies."

Conflict

Although China's military-industrial complex is unlikely to surpass the technological sophistication of the US by 2045, it may rival it in terms of size, as could India's. Both India and China will probably seek to develop sizeable and technically advanced armed forces, including ocean-going navies, capable of delivering an enduring and capable maritime presence both regionally and further afield. The military capabilities of other countries in the region are also likely to increase but only China, India, Australia, Japan (which is actively increasing its military capability) and South Korea are likely to have the ability to project conventional military power globally.

The emergence of India and China as great powers is likely to lead to tensions, both between these two countries and their neighbours that – if not carefully managed – could spill over into conflict. For example, the East and South China Seas are home to a number of disputed territories, and the likelihood of conflict could be increased if dwindling hydrocarbon reserves make the area a more important site for extractions. Similarly, China and India dispute areas of their border; India and Pakistan contest sovereignty over Kashmir; and the Korean peninsula also remains an area of heightened tension. In short, the risk of a major state-on-state conflict in the region cannot be ruled out.

Terrorism will almost certainly remain an enduring factor in the region, particularly in South & East Asia. A variety of terrorist organisations are likely to continue to operate in the region. For example, the Taliban in Pakistan; Kashmiri inspired terrorist groups; an increasingly active Maoist 'Naxalite' insurgency in India (there were nearly 1,900 terrorist

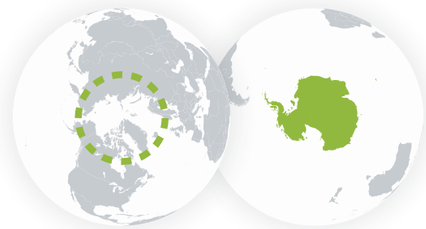
related deaths in India in 2010);[19] and Uighur separatists in China. Although the ability of many of the region's countries to combat terrorism is likely to improve, its developing countries may find it harder to manage such diverse ethno-religious groups.

19 US Department of State (2011), 'Country Reports on Terrorism 2010', available at http://www.state.gov/documents/organization/170479.pdf

Defence and security implications

- In large part because of its economy (likely to be the largest in the world by 2045), South & East Asia will probably be of increasing strategic significance.
- A growing population, increasing demand and the effects of climate change are likely to lead to food and water shortages. While cooperation over water has often overcome national differences, the potential for confrontation over shared water resources may increase.
- Rising sea levels are likely to lead to humanitarian disasters which may require international assistance.
- China's military is becoming more capable and has increasing global reach. By 2045, China's military capability may be close to matching that of the US, perhaps exceeding it in some areas. India's military capability is also likely to increase – but probably not to the point where it rivals China or the US by 2045.
- The East and South China Seas may be flashpoints for confrontation between China and the US and allied countries. Similarly Kashmir, the Korean Peninsula and the border between China and India are likely to be areas of tension. The risk of a major state-on-state conflict in the region cannot be ruled out.
- Terrorism will almost certainly continue to pose a threat in South & East Asia, less so in Oceania. High levels of inequality based upon class, ethnicity and religion are likely to endure as sources of tension across the region and may impact on the overall governance and stability of some countries.

Polar regions



Climate change is the principal driver of change in the Arctic and Antarctic, with increasing temperatures and precipitation. As Arctic and Antarctic sea ice retreats, many areas that are currently inaccessible could become open to commercial exploitation, particularly of oil and gas. The opening-up of the Arctic is likely to focus attention on the region's governance arrangements, but, despite challenges, current arrangements are likely to endure out to 2045. Large-scale military confrontation in either region is unlikely, but it is possible that some countries – depending on their internal politics – may seek to project power in the Arctic if they consider their interests in the region to be under threat. In Antarctica, the current governance arrangements are likely to endure out to 2045, but the Antarctic Treaty System could come under pressure to accommodate increased commercial exploitation within carefully managed bounds.

Arctic

Climate change

Alterations in the climate are the drivers behind many of the changes expected to take place in the polar regions over the coming decades. The impacts of climate change are already being felt, from the reducing area of sea ice during the summer to shifting patterns of rain and snowfall. In the Arctic, significant warming will almost certainly occur throughout the region, and is likely to be greater than the anywhere else in the world.[1] Sea levels will probably continue to rise and precipitation is likely to increase, particularly in winter. Sea ice is likely to reduce, facilitating increased access for shipping. Due to rising temperatures, the permafrost is likely to melt. This could cause subsidence, infrastructure damage and release methane – all adding to global greenhouse gas emissions and exacerbating global warming and its effects, possibly to catastrophic levels. The incidence of severe storms is also likely to increase.

Transit routes

Over the next few decades there is likely to be a sustained reduction in both the extent and thickness of summer sea ice, and regular ice-free summers may occur by 2045. The Arctic navigation season could be extended and new shipping routes have the potential to be opened up. This could save significant time when transporting goods from the Far East to Europe and Northern America. Constraints on the utility of the new Arctic shipping routes for major global trade will probably remain – none are likely to be major trans-global routes by 2045. If countries are to fully exploit hydrocarbon reserves and shipping routes in the Arctic, they will need to invest substantially in icebreaking capacity. As the volume of maritime traffic increases, there is likely to be an associated growth in the environmental risks faced by the Arctic region – and regulating the passage of vessels is likely to pose a significant challenge. The number and magnitude of human disasters requiring search and rescue services is also likely to rise. Measures to improve international

1 Chatham House-Lloyd's (2012), 'Arctic Opening: Opportunity and Risk in the High North', available at http://www.chathamhouse.org/publications/papers/view/182839

Reduction in summer sea ice will extend Arctic navigation routes

coordination and allocate regional responsibilities for providing such services are likely to be developed, but may become entangled in wider disputes over sovereignty.[2]

Resources

Global demand for energy is expected to more than double by 2045, with coal and hydrocarbons likely to continue to play a major role in the global energy mix. The Arctic currently produces around 10% of the world's oil and 25% of its gas, with approximately 80% of these resources coming from Russian territory. It has been estimated that the Arctic contains up to 13% of the world's undiscovered oil and 30% of its gas reserves, which are likely to become increasingly attractive as existing reserves are depleted.[3] Oil and gas exploration is likely to be concentrated in Russia and northern Norway, with other new reserves possible off the seaboards of Greenland, Alaska and the Canadian north. Developing both existing and new oil and gas fields will almost certainly be complex, requiring advances in technology and demanding high standards of engineering and quality control. The Arctic will probably remain particularly vulnerable to oil spills – as a consequence of both the slow recovery of cold ecosystems and the difficulties facing clean-up processes in remote and cold areas where ice is present. It is possible that a major environmental disaster may halt economic exploitation of the region until expensive safeguards have been implemented. A collapse in hydrocarbon prices, though unlikely, could also remove the major economic imperative for development within the Arctic and may lead to major negative impacts on many local and national economies within the region.

Mining of minerals in the Arctic is likely to continue to be a major source of economic development and may expand significantly as sea routes to deep water ports are opened up for bulk carrier access. Deposits of coal, diamonds, nickel, copper, gold, silver, manganese, chromium and titanium are particularly likely to be exploited at an increased level, bringing both money and people into several parts of the region. Although Russia and Canada are likely to possess the largest reserves of these resources, mineral wealth is widely distributed through the Arctic, and there are many areas, including Greenland, with great potential for new discoveries and further exploitation. Commodity prices are likely to rise further, which could provide an extra incentive for more marginal areas to be opened for extraction. However, although exploration and extraction conditions are likely to improve in some areas as the ice retreats, these changing conditions are likely to add new challenges. Melting permafrost, in particular, could impede developing sustainable infrastructure on land. New technology is likely to be needed to exploit mineral extraction potential in many areas affected by melting permafrost, particularly in Russia. Mineral extraction is likely to be harmful to the Arctic environment and adverse ecological impacts could occur.

2 Smith, L. C. and Stephenson, S. R. (2013), 'New Trans-Arctic Shipping Routes Navigable by Midcentury'

3 Chatham House-Lloyd's, *op. cit.*

Agri- and aqua-culture, forestry and tourism

Fishing is already an important source of employment in the region, with several countries, notably Iceland, Russia and Norway, investing in large fishing fleets. Major commercial fish stocks such as cod, herring and pollock are likely to be exploited increasingly easily as sea ice cover reduces, and the areas populated by these fish stocks are likely to increase further in size as the seas warm. For other species of fish, such as salmon and trout, the outlook is less positive, and climate change may significantly reduce these fish stocks. The opening up of the Arctic Ocean, and the possible northwards migration of fish stocks, may – when combined with growing demand for protein in world food markets – encourage large numbers of EU and Asian fishing fleets to move into the region, especially in areas not within countries' exclusive economic zones. By 2045, it is likely that fish stocks in the Arctic will be under severe pressure, potentially causing tensions between Arctic Rim countries, the EU and other fishing countries.

Climate change is already stimulating significant changes to Arctic ecosystems and, as a result, to Arctic agriculture and forestry. The warmer climate is highly likely to extend the growing season and may encourage crop diversification at higher latitudes. Increased crop disease, also as a result of climate change, is unlikely to counteract increased crop yields. Timber productivity is likely to improve, with planted forests in the Arctic likely to expand to the north, despite a likely increase in forest fires and tree-killing pests. Numbers of caribou and reindeer in the region could also rise, although they may be more affected by insect infestations. Diminishing cattle and sheep habitats in southern Europe may create markets for reindeer and caribou products, improving the economic situation of Nordic farmers. Much of the Arctic is also already seeing significant increases in tourist numbers and, by 2045, changes in climatic patterns are likely to have opened up several new Arctic regions as viable tourist destinations.[4]

4 Chatham House-Lloyd's, *op. cit.*

Governance

The Arctic region, comprising four million people, eight countries and over 30 indigenous groups, is largely under-populated and is characterised by sparse communication and infrastructure links. Out to 2045, there are likely to be significant increases in using, and extracting, the region's resources and developing its transport links. This is already beginning to render its governance arrangements of deep significance and could lead to increased tensions within the countries and peoples of the region. International governance, regional groupings and non-state actors are all likely to play important roles within the Arctic.[5]

By 2045, it is unlikely that there will be any appetite for a formal UN agreement setting a legally binding governance framework for the Arctic region (as exists in Antarctica). The delineation of countries' exclusive economic zones and continental shelf boundaries under the UN Convention on the Law of the Sea (UNCLOS) process will probably establish the ownership of economic rights in the vast majority of the Arctic Ocean, and it is unlikely that Arctic countries would attempt to overturn these decisions by force. Although tension between countries over interpreting the UNCLOS criteria for claiming jurisdiction may increase during the period leading up to 2045, it is likely that competing claims will be arbitrated such that each country will be able to exploit large areas of the Arctic sea bed beyond its exclusive economic zones. The UN Security Council will almost certainly continue to provide a forum for countries located outside the Arctic (but with national interests within it) to discuss economic and political issues as they arise.

New regional governance arrangements are also unlikely to materialise, primarily because it is not likely to be in the national interests of

"It is unlikely that there will be any appetite for a formal UN agreement setting a legally binding governance framework for the Arctic region."

5 *Ibid.*; Holte, N. J. (2009), 'The Arctic Region is at a Time of Geopolitical Transition. Will this Transpire Through Aggressive Competition or as Peaceful Change?', available at http://www.da.mod.uk/colleges/rcds/publications/seaford-house-papers/2009-seaford-house-papers/shp09holte.pdf; Rogers, J. (2012), 'Geopolitics and the 'Wider North': the United Kingdom as a 'Strategic Pivot'

Isolated and sparsely populated areas are likely to see development of infrastructure and transport links

"The EU is likely to become more involved in the Arctic as non-Arctic EU members, such as Germany and the UK, become more dependent on the region's energy resources and fish stocks."

Arctic countries for them to do so. Although the Arctic Security Forces Roundtable (a semi-annual gathering of senior military officers) is currently informal, it has the potential to develop into a more structured forum for international coordination by 2045. The Arctic Council is likely to continue to provide a focus for all Arctic countries and peoples. It may consider some form of low-level economic collaboration, but is unlikely to expand into the governance or security sphere. The influence of the indigenous peoples is also likely to be limited and dispersed, and focussed on exerting pressure on multinational corporations and authorities within their countries to secure better economic conditions. Indigenous people are also likely to continue to exert influence through their position at the decision-making table of the Arctic Council. The EU is, however, likely to become more involved in the Arctic as it is likely to expand to incorporate Arctic countries and as larger non-Arctic EU members, such as Germany and the UK, become more dependent on the region's energy resources and fish stocks.

Canada

The Arctic is likely to be an increasingly important region for Canada out to 2045. Melting ice is likely to open new areas for mining, hydrocarbon extraction, fishing and shipping during the summer months. Canada will probably continue to emphasise the Arctic's importance to its national interests. It may also continue to reject US and Danish claims to rights of navigational passage within its exclusive economic zone. Despite these disagreements, Canada is likely to maintain good relations with both nations. Canada and the US are likely to reach an agreement on a range of Arctic issues, particularly over gas and oil distribution pipelines from the Arctic to the markets of Northern America.

China

By 2045 China could have substantial maritime power and may look to an accessible Arctic as a channel for trade and fishing in the region. To maintain these trading routes, China may deploy its naval forces, which may heighten tensions with Russia. China may also seek to extend itself economically into the Arctic, again risking conflict, although violence is unlikely.[6]

Russia

Russia will almost certainly be the dominant – but unpredictable – state actor in the Arctic by virtue of its economic, political and military strength in the region, as well as its location and size. Russia is likely to have sovereignty over the region's major fossil fuel reserves, fish stocks and mineral deposits, and climate change could afford it the possibility of expanding its agricultural sector in the region. Russia is also likely to have significant influence over the Northern Sea Route as it becomes more viable to commercial traffic as summer ice retreats. Russia's Arctic region is currently the source of 20% of its GDP, 60% of its oil and 90% of its gas, and the country's leadership will probably continue to view it as a strategic interest. Russia is likely to continue to maintain significant military capabilities in the Arctic to protect its nuclear forces and secure its economic assets, as well as providing a basis for its search and rescue responsibilities. There may be more frequent demonstrations of military strength in the air and at sea, possibly to distract from domestic sociopolitical issues.

The United States of America

The US, while seeking to ensure that its economic and security interests are protected, is unlikely to see the Arctic as a primary theatre of American activity. However, there may be tension with Russia over disputed areas of the Chukchi Sea, and US control of fishing within the Bering Sea may be challenged by Russian, Chinese, Korean and Japanese interests if the region continues to be a significant source of fish and sea mammals.

Other Arctic countries and populations

Norway will almost certainly continue to rely on NATO as the guarantor of its security, though it is likely to seek further bilateral agreements with EU countries to reinforce its position. More advanced than the other countries in setting out a vision for the region, it is likely to retain the lead in Arctic regional development. A newly independent Greenland may seek to join the EU and NATO, and could become the subject of intense interest from countries such as China. Out to 2045, Iceland may also seek EU membership as well as more substantive engagement with other NATO members.

The indigenous populations of the Arctic are likely to see their lifestyles threatened, their numbers declining, and their influence waning. Their unique lifestyle and patterns of subsistence are likely to have disappeared by 2045, and the need to assimilate and to gain new skills to compete with skilled migrants from the south is likely to be both an opportunity and a risk. The indigenous population within the Arctic is likely to decline slowly, and may undergo some degree of urbanisation as its members move in search of healthcare and employment opportunities for their young people. It is unlikely that the regional peoples will be able to counteract the power and influence of their largely sub-Arctic based governments and their influence will probably remain largely peripheral (except Greenland's large Inuit population). Tension and low level violence between migrants and indigenous people is possible.

Multinational corporations

Many of the inhabited areas of the Arctic will probably continue, in practice, to be managed by multinational corporations and populated solely or predominantly by their workers. Russian-based conglomerates are likely to remain semi-state controlled. They are unlikely to operate to levels of corporate governance expected in the West and are likely to be less inclined to comply with international regulations. Environmental pressure groups and non-governmental organisations, such as the World Wildlife Fund and Greenpeace, could play an increasing role in influencing the activity of western countries and corporations in the Arctic region.

"Russia's Arctic region is currently the source of 20% of its GDP, 60% of its oil and 90% of its gas."

6 Blank, S. (2013), 'China's Arctic Strategy', available at http://thediplomat.com/2013/06/20/chinas-arctic-strategy/

Antarctic

Climate change

Across Antarctica as a whole, land temperatures could rise by more than 2°C by 2045, and sea temperatures in the region are also likely to continue to rise, albeit at levels below the global average. An increase in average annual maximum precipitation of 7% is likely by 2045 (compared with 1999 levels), and parts of Antarctica and its surrounding seas will almost certainly continue to lose ice at a rapid rate up to, and beyond, 2045. The effects of climate change on Antarctic ecosystems are likely to be significant. Melting Antarctic ice may contribute to sea-level rises, with a subsequent effect on the rest of the planet.

Resources

Global demand for minerals, fossil fuels and low-emission energy sources are likely to continue to rise until at least 2045, providing an incentive to operate in previously unexploited areas. Although the Antarctic Treaty explicitly prohibits extracting minerals and hydrocarbons (other than for scientific research purposes), the potential for their extraction in Antarctica is likely to become a significant influence on the region's geopolitics in the coming decades. It is already likely that substantial hydrocarbon deposits exist, including in the area triple-claimed by the UK, Argentina and Chile. Drilling, however, is likely to remain uneconomical unless oil prices rise well above their current level or until technological advances lower the cost of exploitation significantly. Nevertheless, given probable global demand levels, proposals for exploitation are likely by 2045 if hydrocarbon deposits have been found on the continent and in its surrounding waters. Any proposals for exploitation could heighten political tensions in the region, and may not even be accepted given the likelihood of strong opposition from certain countries and from environmental pressure groups. Exploiting hydrocarbon deposits in Antarctica is likely to damage the local environment and could bring about grave consequences for the continent's ecosystems. Although the geography of Antarctica lends itself to producing renewable energy, it is unlikely to be economically viable to do so by 2045.

"Although the Antarctic Treaty explicitly prohibits extracting minerals and hydrocarbons, the [economic] potential is likely to become a significant influence on the region's geopolitics."

Although there is much uncertainty about the extent and nature of mineral deposits, early studies indicate that Antarctica is likely to contain mineral deposits similar to those in Australia, Africa, India and South America, to which it was once joined. The Dufek Massif – which lies within the area triple-claimed by the UK, Argentina and Chile – is the location with the most significant potential mineral endowments within the Antarctic continent. All nations currently carrying out scientific research on Antarctica are likely to maintain a keen interest in its mineral potential, with China foremost among them. Nevertheless, there are several physical, environmental and technological factors that effectively prevent mining in Antarctica, some of which may not – as a result of melting ice and technological advances – be present by 2045. Significant opposition to exploiting Antarctica's mineral wealth is, however, likely to remain, based on environmental protection grounds. Although some Antarctic Treaty System members, as well as non-member nations, may lobby for mining to be allowed to ease economic pressures, there is likely to be strong pressure from other nations and non-state actors to maintain the status quo, preserving continental Antarctica from commercial activity.

Water

By 2045, one third of the world's population is likely to live in areas of water stress. In the developed world, water scarcity is likely to be overcome mainly through conservation and the increased use of desalinisation (which is extremely energy-intensive). Some estimates suggest that 90% of the world's fresh water is in Antarctica,[7] mostly in the ice sheets that flow to the continent's coast and in the many ice shelves floating on the sea. These vast quantities of ice may hold part of the solution to world water shortages, particularly if better and cheaper technology enables the establishment of a commercial iceberg harvesting industry. Although this could generate worldwide benefits, such commercial exploitation could bring negative environmental consequences to Antarctica, including damage to ecosystems.

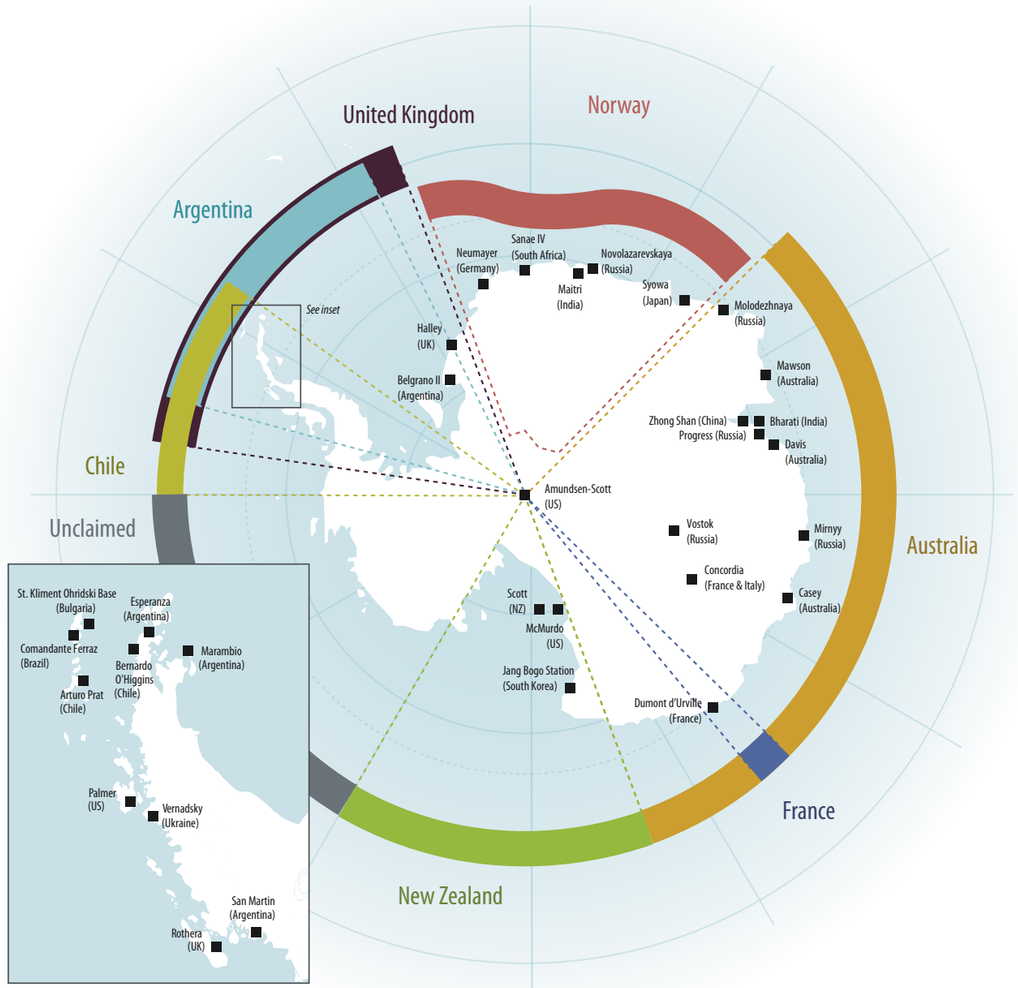
7 British Antarctic Survey (undated), 'Ice Sheets in Antarctica', available at http://www.antarctica.ac.uk/about_antarctica/geography/ice/sheets.php

Fishing

Commercial exploitation of Antarctica's marine resources has taken place for over a century, and has evolved markedly since the 1950s in response to a range of drivers, particularly resource demand. Control mechanisms have been developed that have adequately dealt with fisheries management and lowered political tensions. Under these mechanisms fish and krill are the only Antarctic living resources whose exploitation has been sanctioned. However, an increase in demand during the period leading up to 2045 is likely to put these control mechanisms and associated political relationships under strain, and the Convention on the Conservation of Antarctic Marine Living Resources is likely to have to be amended to reflect higher levels of demand – or face being flouted.

Abandoned whaling ship in Antarctica – a legacy of resource exploitation

Antarctic territorial claims and permanent research stations



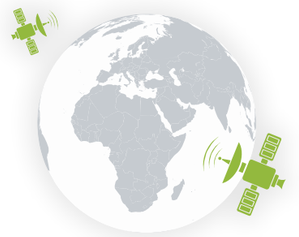
Governance

The Antarctic Treaty System is likely to endure, but may be subject to disputes as countries deal with climate change, population increase, resource scarcity and global inequality. These stresses are highly likely to cause tensions between Antarctic Treaty System members, and between them and other countries. Any discovery of significant resources – especially hydrocarbons or strategic minerals – on the continent is likely to further increase the pressure. Although a resource-driven scramble for the Antarctic is unlikely, incremental increases in exploiting the area under the Antarctic Treaty System are expected. The global scientific community is likely to act in concert to halt the open exploitation of Antarctica for economic ends, but is unlikely to be able to stop incremental increases in exploitation. While it is also unlikely that the prohibition of military activity in the region will be breached (military support to civil activity is likely to continue to be permitted), there may be a considerable increase in military activity in the surrounding seas and airspace, influenced by increased competition for Antarctic resources.

Defence and security implications

- Commercial activity expansion in the Arctic Ocean may require extensive monitoring to safeguard Arctic countries' sovereignty.
- Arctic Council members, in general, are likely to continue to operate in accordance with its rules – the Arctic is likely to remain a largely well-governed space.
- Inter-country disputes within the Arctic, driven by access to, and control over, resources, are possible but are unlikely to result in military conflict.
- Russia will almost certainly remain the dominant power in the Arctic but, although unpredictable, is unlikely to take unilateral, aggressive steps to provoke conflict in the region.
- Resource demands are likely to increase pressure on the Antarctic Treaty System, but large-scale military conflict is unlikely.

Space



Our reliance on space technology in a number of commercial and military areas will almost certainly increase out to 2045. Technological advances are likely to further reduce the cost of manufacturing and launching space vehicles, making space increasingly accessible to (and profitable for) countries, companies, organised crime and private individuals. As reliance on space grows, so could the impact of damage caused by deliberate attack, space weather and orbital collisions.

Relying on space-based technology

Developed countries already depend heavily on space-based technologies and this reliance is likely to increase out to 2045, with many developing countries also likely to seek similar capabilities. Almost 60 countries currently have satellites or space projects with significant levels of investment – there are an estimated 3,400 satellites in orbit, of which around 1,000 are operational.[1] Some estimates put replacement costs for these active satellites at nearly US$ 140 billion, with the impact of their loss on the global economy several times higher.[2] Activity in space is increasing, and may well accelerate. In total, governments (including Kazakhstan, the Congo and Laos) spent more than US$ 40 billion on civil space programmes in 2013 alone.[3] These high levels of investment are driven by the critical role that space-based technologies now play in routine activity. For example, global navigation satellite systems (GNSS) are used to provide essential position, navigation and timing information for industries as diverse as agriculture, finance, surveying, emergency services, energy distribution, wireless technology and rail transport. GNSS are also crucial for commercial aviators and sailors, and many departments of defence use space systems for global communication and to collect remote sensing imagery of points of interest on the Earth. The accuracy of modern weather forecasts also relies on satellite imaging and sensing.

Decreasing costs and improving access

The traditional view of a satellite as a large, expensive object is being increasingly challenged by the use of ever-smaller devices (some nicknamed 'cubesats'), often no larger than 10 cm^3 and weighing as little as a kilogram. Small satellites usually operate in low-Earth orbits and take advantage of commercial off-the-shelf components to reduce production costs and development times. Some commercial organisations are already using constellations of cubesats to generate Earth imagery,[4] and their use is only likely to grow as their effectiveness and reliability are proven. Industry sources anticipate that up to 543 cubesats and microsatellities (up to 50kg in weight) could be launched in 2020, compared to

1 European Space Agency (2013), 'Space Debris: Frequently Asked Questions', available at http://www.esa.int/Our_Activities/Operations/Space_Debris/FAQ_Frequently_asked_questions

2 *Ibid.*

3 The Economist (2014), 'Ye Olde Space Race', available at http://www.economist.com/blogs/graphicdetail/2014/02/daily-chart-11

4 Such as Planet Labs, http://www.planet.com/

92 in 2013.[5] With greater access, though, comes greater competition, particularly for allocating satellite orbital slots and radio frequencies. A more optimistic view is that, with more space objects and potentially more collisions, there is a greater need to develop and abide by international standards and to create as complete a picture as possible of all activity in space. Notwithstanding the trend towards greater collaboration between groups of countries, attempts to introduce a comprehensive, effective and binding legal framework have so far been unsuccessful.

New economic opportunities

As space becomes more accessible through significant advances in the development of spaceplanes (vehicles that can operate in the Earth's atmosphere as well as in space) and reusable rockets, new economic opportunities are likely to emerge. Several companies are already proposing to extract water and minerals from asteroids that travel near Earth. One of these companies, Planetary Resources, is hoping to launch its first spacecraft in 2014, with prospecting platforms operating in the next decade. By 2045, companies pursuing off-Earth resources are likely to have extensive operations, particularly if the potential revenues are as significant as suggested by some analysts.[6] For example, a single asteroid (1999 JV6) which passed the Earth in January 2014 could generate mining profits of up to US$ 218 billion.[7] Space tourism – both sub-orbital and orbital – is also a real possibility by 2045, with a number of projects currently in development. These potential economic benefits, along with continuing reductions in operating costs, make it likely that there could be greater space congestion as more countries, commercial operators and even individuals deploy orbital systems. Indeed, the UN recently commented that "The outer space environment [is] becoming increasingly 'congested, contested and competitive' as States [vie] to benefit from space based technologies."[8] Orbiting laboratories could become viable, with some companies aiming for orbital platforms with significantly greater capacity than the International Space Station.[9] In turn, this has the potential to lead to breakthroughs in the development of new medicines and materials that require a micro gravity environment.

"The European Commission has estimated that 6-7% of western countries' GDP is currently dependent on satellite timing and navigation: this equates to €800 billion for the EU alone."

Vulnerabilities

Our reliance on space technologies generates widespread vulnerabilities which are likely to increase in the future. The UK Government's National Risk Assessment ranked severe disruption to satellite services, possibly as the result of a deliberate attack by another state, in the second highest category of security risks faced by Britain.[10] Similarly, a US Government report observed that lives and billions of dollars could be lost if significant disruption to global positioning systems (GPS) occurred.[11] The European Commission has estimated that 6-7% of western countries' GDP is currently dependent on satellite timing and navigation: this equates to €800 billion for the EU alone.[12] As well as deliberate threats, satellites are at risk from man-made space debris, space weather and from accidental collision with each other. Such collisions have already occurred, and this risk is likely to grow as more man-made objects are launched into space.

5 Spaceworks (2014), 'Nano/Microsatellite Market Assessment', available at http://www.sei.aero/eng/papers/uploads/archive/SpaceWorks_Nano_Microsatellite_Market_Assessment_January_2014.pdf

6 Knight, O. (2014), 'To Infinity and Beyond for Property', available at http://www.knightfrankblog.com/wealthreport/news-headlines/to-infinity-and-beyond-for-property/

7 *Ibid.*

8 UN (2013), '68th General Assembly GA/DIS/3487 Press Release', available at http://www.un.org/News/Press/docs/2013/gadis3487.doc.htm

9 Bigelow Aerospace (undated), 'Mission Statement', available at http://www.bigelowaerospace.com/

10 HM Government (2010), 'A Strong Britain in an Age of Uncertainty: The National Security Strategy', available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61936/national-security-strategy.pdf

11 US Government Accountability Office (2013), 'GPS Disruptions', available at http://www.gao.gov/assets/660/658792.pdf

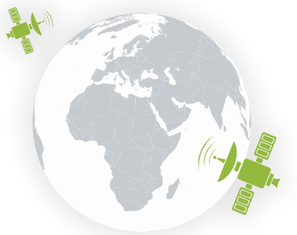
12 European Commission (2012), 'Galileo Will Boost Economy and Make Life of Citizens Easier', available at http://europa.eu/rapid/press-release_MEMO-11-717_en.htm?locale=en

Criminal use of space

Criminals and other actors with malign intent may increasingly exploit space-based capabilities, particularly as access becomes cheaper. Already, those who wish to discover weaknesses in the security arrangements of sensitive infrastructure can buy high resolution imagery from companies that operate Earth observation spacecraft. By 2045 or earlier, criminal organisations could secure payload space on rockets operated by private companies – this would allow them to launch their own surveillance satellites, potentially threatening individual and corporate privacy.

Jamming

Ground-based receivers of satellite signals have already been jammed for short periods in localised areas. In 2009, navigation aids at Newark airport suffered daily breaks in reception, caused by a driver with a GPS jammer who regularly drove past. Drivers are likely to continue to use jammers to prevent their location being monitored by their employers and criminals may increasingly use them to avoid paying GNSS-based road tolls. Perhaps more significantly, North Korea has used large, lorry-based jammers to interfere with GPS signals in South Korea – the crews of more than 1,000 aircraft and 250 ships reported disruptions over a 16-day period in 2012.



Chain reactions and deliberate attacks

The large amount of space debris currently in orbit – an estimated 670,000 objects larger than one centimetre and 29,000 larger than ten centimetres[13] – increases the risk of a chain reaction of collisions which could render low-earth orbits unusable, disabling most surveillance satellites and threatening access to higher orbits. Some debris mitigation measures are already in place, such as providing extra fuel for manoeuvring near-defunct satellites into the atmosphere so that they burn up. However, the European Space Agency suggests that, even if satellite launches were stopped today, a chain reaction of collisions is likely within 20 years, unless some of the debris currently in orbit is removed.[14] Prototype machines for removing

13 European Space Agency, *op. cit.*

14 Klinkrad, H. (2013), 'The Space Debris Environment', a presentation to the Royal Aeronautical Society

Reliance on space technologies generates widespread vulnerabilities

Scenario:

A city without space[15]

By 2045, a solar superstorm of a similar size to the Carrington Event of the mid-1800s could occur and be so disruptive that there would be widespread loss of communications and navigation systems for several days, with possible permanent loss of some satellites. Transport and logistic systems dependent on GNSS would be disrupted - flights would be cancelled and planes already in flight may be unable to navigate to safe landing areas, potentially causing loss of life. Roads and railway networks are likely to become congested as drivers find themselves lost. Vehicles carrying high risk or hazardous loads are often tracked by satellite - they would disappear from the screens of monitoring centres, potentially resulting in accidents.

Assisting casualties could be delayed as, without GNSS, the emergency services would take longer to arrive at the scene. If traditional means of navigation had not been retained, emergency vehicles may not be able to reach their destination at all. Logistics networks are likely to be disrupted and - depending on duration - this could lead to bare shelves in shops, as most supermarkets hold very limited amounts of stock, relying on daily deliveries. Criminals may take advantage of a lack of coordination and delayed response times to loot and riot.

15 Based on Hammond, J. (2012), 'Increased Problem of GPS Jamming', lecture delivered at the RUSI Space and UK National Security Conference

"The risk of creating space debris may make countries or groups think more carefully before carrying out a deliberate physical attack on satellites."

malfunctioning satellites and debris are being developed, but international law only allows the country that owns (or the agency that launched) a spacecraft to touch it – as technology able to remove an obsolete satellite could equally be used to interfere with an operable one. The risk of creating space debris may make countries or groups think more carefully before carrying out a deliberate physical attack on satellites. Although some countries already have the capability to carry out this kind of attack, the fragments created if a satellite was destroyed in a usable orbit could also deny access to space to the perpetrator. However, this could make space assets an attractive target for those countries or groups that either do not rely on space-based systems or that have developed resilient systems or processes. Cyber attacks on control networks may be more likely, and there is some evidence that such attacks are already occurring. In 2008, a NASA Earth observation satellite was effectively taken over, although those responsible did not actually issue commands.[16]

Space weather

Although most satellites are designed to deal with the effects of minor space weather (such as disturbed orbits and radiation), they are not usually able to withstand the effects of solar superstorms. These extreme events can cause severe disruption. In 1989, for example, the biggest storm to reach Earth for 50 years led to space agencies losing track of 1,600 spacecraft and the power grid of Quebec collapsing in two minutes, leaving six million people without power for nine hours. Similarly, in 2003, a superstorm interrupted the Federal Aviation Authority's augmented GPS signal (used for aircraft vertical guidance) for 30 hours. Far more disruptive storms may, however, affect the Earth in future.[17] In 1859 the Carrington Event (a storm four times stronger than any of the examples above)[18] struck the Earth. Some experts suggest that a storm of Carrington's magnitude is likely to reach Earth once every 100 years.

16 US-China Economic and Security Review Commission (2011), '2011 Report to Congress', available at http://origin.www.uscc.gov/sites/default/files/annual_reports/annual_report_full_11.pdf

17 Hapgood, M. (2012), 'Prepare for the Coming Space Weather Storm'

The effects of a superstorm like the Carrington Event may lead to satellites being offline for periods ranging from hours to days. Some may even be lost entirely due to sudden damage, such as that caused by electrostatic charging. All satellites would have their effective lives reduced through exposure to an increased radiation dose. Solar radio bursts would be likely to interfere with GNSS transmission frequencies, with possible errors of hundreds of metres. During the main phase of a superstorm, navigational systems may be completely lost, with some experts suggesting that GNSS could be partially or completely inoperable for up to three days. Communication satellites' radio transmissions and long-range terrestrial radio could also be affected, making long distance communication during a superstorm particularly challenging.

Military operations

Military activity, at least in developed countries, has come to rely on space-derived services, a trend that is likely to increase out to 2045.[19] If space capabilities were lost, modern armed forces could be without many of the advantages that they currently enjoy. A lack of strategic communications would make direct command and control links impossible, hampering coordination with military partners and making most remotely-piloted air systems inoperable. Early warning systems would be compromised, removing the ability to provide warnings of ballistic missile launches or to track and monitor missiles in flight. Navigation would be more difficult, relying on maps and compasses – and it is even possible that compasses would not function properly if the Earth's magnetic field was sufficiently disrupted. Collateral damage may increase, as precision-strike capabilities disappear. Limited surveillance and radar capabilities would make it more difficult to select the highest-value targets or conduct timely battle damage assessment. Without accurate weather forecasting, effective planning would be difficult and operations would be riskier without warning of extreme events or conditions. Logistics would be disrupted as tracking and monitoring supplies could become more difficult.

18 Royal Academy of Engineering (2013), 'Extreme Space Weather', available at http://www.raeng.org.uk/news/publications/list/reports/space_weather_full_report_final.pdf

19 Ministry of Defence (2013), 'JDP 0-30 UK Air and Space Doctrine', available at http://defenceintranet.diif.r.mil.uk/libraries/library1/MOD/July2013/20130716-JDP_0_30_UK_Air_and_Space_Doctrine.pdf

Defence and security implications

- Increasing reliance on space-based technologies, particularly in developed countries, means that any large-scale disruption to satellites (such as solar superstorms) could have significant consequences for electricity distribution, communications, navigation, logistics and weather forecasts.
- There could be increasing competition between countries for access to valuable resources, such as water and minerals, located in space.
- Criminal organisations and other actors with malign intent may take advantage of reduced costs to acquire their own satellites, increasing their awareness of security vulnerabilities and causing privacy and security concerns.
- The military operations of developed countries are heavily dependent on space-based technologies, the loss of which may be significantly disruptive.

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