Chapter 1

Megatrends affecting science, technology and innovation

This chapter describes and analyses the main global "megatrends" that are set to have a strong impact on societies and economies, including science, technology and innovation (STI) systems, over the next 10-15 years. Megatrends are large-scale social, economic, political, environmental or technological changes that are slow to form but which, once they have taken root, exercise a profound and lasting influence on many if not most human activities, processes and perceptions. Such relative stability in the trajectory of major forces of change allows some elements of a likely medium-to-long term future to be envisioned, at least with some degree of confidence. The megatrends covered in this chapter are clustered into eight thematic areas as follows: demography; natural resources and energy; climate change and environment; globalisation; the role of government; economy, jobs and productivity; society; and health, inequality and well-being.

Introduction

Our future is uncertain, shaped by a multitude of powerful, complex and interconnected forces, and eventually altered by improbable, unpredictable and highly disruptive events. Seen over a time horizon of say 10-20 years, some of the big trends we see unfolding before us are in fact quite slow-moving. These are megatrends – large-scale social, economic, political, environmental or technological changes that are slow to form but which, once they have taken root, exercise a profound and lasting influence on many if not most human activities, processes and perceptions. Examples are global population growth and urbanisation, or the ageing of societies in many parts of the world; the warming of the planet and rising sea levels or the acidification of our oceans and seas; the deepening of globalisation; and the growing momentum of digitalisation, big data and bioengineering.

The relative stability in the trajectory of these major forces of change allows us to envision at least some elements of our likely medium-to-long term future with some degree of confidence. What often tends to shake that confidence, at least temporarily, are disruptive events. These come in a multitude of forms and include natural disasters and catastrophes and events related to human intervention, e.g. sudden peaks of violence, large-scale accidents, and economic and political crises. Such events are difficult to build into trend projections, and so are often treated in forward-looking exercises as "wild cards", defined as high-impact events that are unpredictable or unlikely to happen. Potentially disruptive scientific and technological innovation frequently find a place in forward trend studies, not least because they often occur as an extension of, or as a marked departure from, existing science and technology (S&T) trends. Ultimately, it is how megatrends and disruptive trends – especially in the field of S&T – interact that will set the scene for the coming decades. It is for governments, business, researchers and citizens in general to reflect on what the interplay of such trends means in terms of opportunities to be seized and challenges to be met.

In this regard, foresight can be a useful tool for developing and implementing forward-looking research and innovation policies. Analysis of future trends, whether derived from extrapolations, simulations, projections or scenarios, can provide important insights for the future. Foresight can offer support and guidance for decision makers and investors, and alert policy makers, the business community, researchers and society more generally to important upcoming issues. The interpretation of future trends, however, always needs to be done with care: they do not foretell the future, but merely indicate how the future might evolve under certain conditions and in a given subject area. By bringing together and closely examining the interplay between trends in different subject areas, it is possible to assemble a somewhat fuller picture of possible futures. This can strengthen the basis for developing narratives or storylines, which in turn can enrich our view of where the world is heading and what challenges and opportunities may lay on or beyond the longer-term horizon.

This chapter covers those megatrends that are expected to have a strong impact on science, technology and innovation (STI) systems. The megatrends covered are clustered into eight thematic areas, as shown in Figure 1.1. While the time horizon adopted in this

STI outlook is 10-15 years, several megatrend projections presented below stretch somewhat longer into the future. This in part reflects the availability of data. It also reflects the fact that large discernible changes for some megatrends are best seen over longer time horizons of 20 years or more. Irrespective of the time horizons adopted, there are implications for STI policy today. Indeed, this focus on the need for policy (re)orientation has guided the choice of megatrends featured below.

By way of overview, some of the main megatrends covered include the following:

- **Demography:** The world population will continue to grow in the 21st century and is expected to nudge the 10 billion mark by mid-century. Africa will account for more than half of this growth, which will generate significant youth bulges. Elsewhere, including in many developing countries, populations will significantly age, and those over 80 will account for around 10% of the world's population by 2050, up from 4% in 2010. With a declining share of the population in work, ageing countries will face an uphill battle to maintain their living standards. International migration from countries with younger populations could offset this decline. At the same time, technologies that enhance physical and cognitive capacities could allow older people to work longer, while growing automation could reduce the demand for labour.
- **Natural resources and energy:** A growing population coupled with economic growth will place considerable burdens on natural resources. Severe water stress is likely in many parts of the world, while food insecurity will persist in many, predominantly poor, regions. Energy consumption will also rise sharply, contributing to further climate change. Global biodiversity will come under increasing threat, especially in densely populated poorer countries.
- **Climate change and environment:** Mitigating the considerable extent and impacts of climate change will require ambitious targets for the reduction of greenhouse gas emissions and waste recycling to be set and met, implying a major shift towards a low-carbon "circular economy" by mid-century. This shift will affect all parts of the economy and society and will be enabled by technological innovation and adoption in developed and developing economies.
- **Globalisation:** The world economy's centre of gravity will continue to shift east and southwards, and new players will wield more power, some of them states, some of them non-state actors (such as multinational enterprises and NGOs) and others newly emerging megacities. Driving and facilitating many of these shifts in power and influence is globalisation, which operates through flows of goods, services, investment, people and ideas, and is enabled by widespread adoption of digital technologies. But globalisation will inevitably face counter-currents and crosswinds, such as geopolitical instability, possible armed conflict and new barriers to trade.
- **Role of government:** Governments will be compelled to respond to the many grand challenges arising in the future in a context marked by mounting fiscal pressure, eroding public confidence in government and the continuing transition to a multipolar world, with the consequent potential for growing instability.
- **Economy, jobs and productivity:** Digital technologies will continue to have major impacts on economies and societies. Over the next 15 years, firms will become predominantly digitalised, enabling product design, manufacturing and delivery processes to be highly integrated and efficient. The costs of equipment and computing will continue to fall, while the rise of open source development practices will create further communities of

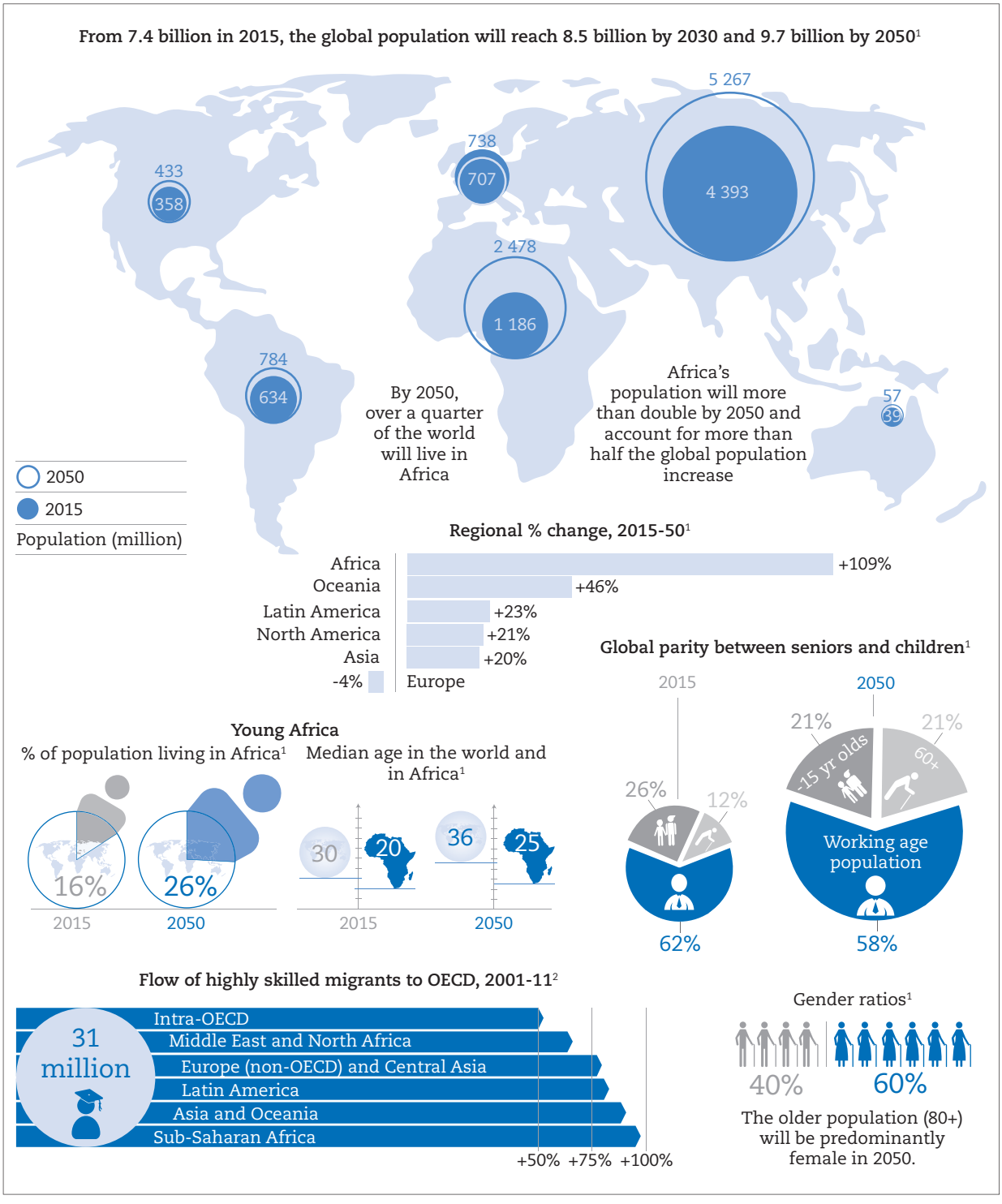
developers. There will be greater opportunity for entrants – including individuals, outsider firms and entrepreneurs – to succeed in new markets. At the same time, the decreasing cost of computing power and advances in machine learning and artificial intelligence will further disrupt labour markets, with one in ten jobs in OECD countries at high risk of being automated over the next two decades.

- **Society:** The future will see striking changes in family and household structures in OECD countries with significant increases in one-person households and couples without children. Access to education and acquisition of skills will be one of the most important keys to improving life chances. Growth in female enrolment at all levels of education will continue, and will have important implications for labour markets and family life. The global population will be increasingly urban, with 90% of this growth occurring in Asia and Africa. Urbanisation could bring several benefits to developing countries, including better access to electricity, water and sanitation. But it could also lead to extensive slum formation with negative consequences for human health and the environment.
- **Health, inequality and well-being:** The treatment of infectious diseases that affect the developing world disproportionately will be further compromised by growing antibacterial resistance. Non-communicable and neurological diseases are projected to increase sharply in line with demographic ageing and globalisation of unhealthy lifestyles. Inequalities will grow in many developed countries, as will poverty rates and the profiles of those at risk of poverty.

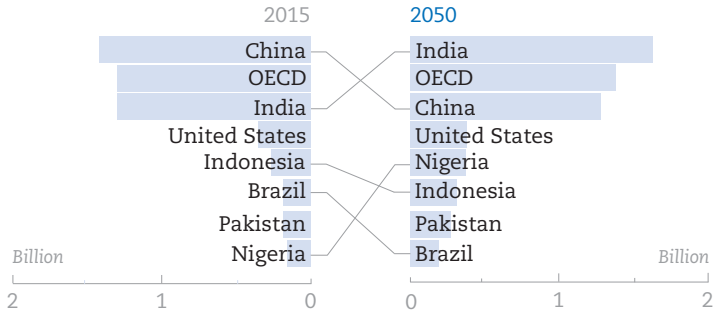
In this changing world, STI can work as a double-edged sword. On the one hand, technological advances have the potential to reinforce the destabilising effects of many of the megatrends described here. On the other, they have the potential to improve humankind's response to many of the global challenges facing the planet. Either way, they will have a major influence, often in unexpected ways.

Eight megatrend areas covered in this chapter

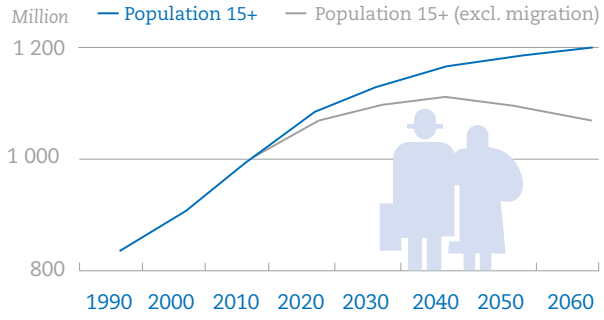
Demography


From 7.4 billion in 2015, the global population will reach 8.5 billion by 2030 and 9.7 billion by 2050[1]
5 267
4 393
738
707
433
358
2 478
1 186
784
634
57
39
2050
2015
Population (million)
By 2050, over a quarter of the world will live in Africa
Africa's population will more than double by 2050 and account for more than half the global population increase
Regional % change, 2015-50[1]
Africa +109%
Oceania +46%
Latin America +23%
North America +21%
Asia +20%
Europe -4%
Global parity between seniors and children[1]
2015
2050
26%
12%
62%
21%
21%
<15 yr olds
60+
Working age population
58%
Young Africa
% of population living in Africa[1]
16%
26%
2015
2050
Median age in the world and in Africa[1]
30
20
36
25
2015
2050
Flow of highly skilled migrants to OECD, 2001-11[2]
31 million
Intra-OECD
Middle East and North Africa
Europe (non-OECD) and Central Asia
Latin America
Asia and Oceania
Sub-Saharan Africa
+50% +75% +100%
Gender ratios[1]
40%
60%
The older population (80+) will be predominantly female in 2050.

Most populous countries[1]

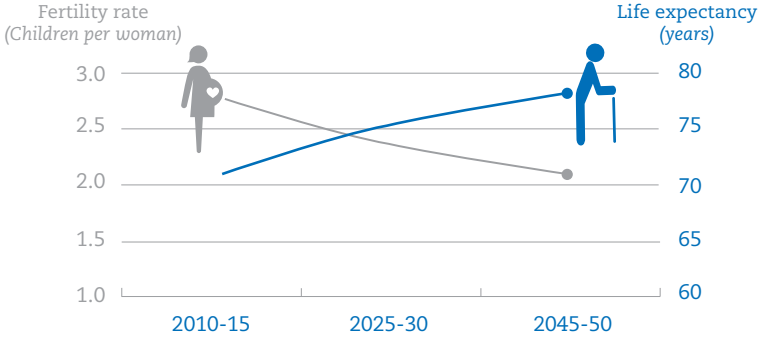


Population and migration
OECD, 1990-2060[3]



Migrant workers will be an important factor to mitigate the effects of ageing in most OECD countries.

Fewer births and longer life spans[1]



The population in all major regions of the world is ageing.

Growing global population

- A larger global population, together with increased educational attainment and economic development, will likely translate into more consumers, innovators and researchers at a global level.
- The demands and needs of the centres of largest population growth, e.g. in Africa, could increasingly shape innovation agendas. These areas will also further develop localised research and innovation capabilities.
- A greater focus on technology transfer to centres of largest population growth will likely be needed to help them manage the multiple development challenges they face.

Ageing societies

- Ageing societies could see slower economic growth and resources diverted to social and health spending. This could draw resources away from STI spending.
- Ageing implies changes in lifestyle and consumption patterns, which will influence the types of products and services in demand and the direction of innovation.
- Ageing-related illnesses, including cancer and dementia, will increasingly dominate health research agendas.
- New technologies, e.g. robotics and neurosciences, could help the elderly live longer, healthier and more autonomously.

Labour and international migration

- Fewer people of working age will affect the labour market for STI skills and could lead to an ageing research workforce in OECD countries.
- The flow of highly skilled migrants into OECD countries is likely to intensify, further contributing to the STI labour force.
- Though much debated, new technologies, e.g. robotics and artificial intelligence, could alleviate expected labour shortages in the wider economy.

Sources: 1. UNDESA (2015a). The population refers to persons aged 15 and above. Iceland is excluded from OECD destinations when comparisons between 2000-01 and 2010-11 are made.; 2. OECD (2015a); 3. Westmore, B. (2014).

Population growth in less developed countries

The world's population is expected to grow during the 21st century, though at a slower rate than in the recent past, reaching 8.5 billion by 2030 and 9.7 billion by 2050. Growth will take place almost entirely in less developed countries and Africa will account for over half of the expected increase. Population size in much of the developed world will stabilise and many countries will even experience a population decline. In Japan and much of Central and Eastern Europe, for example, populations are expected to fall by more than 15% by 2050.

Global population growth will place unprecedented pressures on natural resources, e.g. food, energy and water, and STI will continue to be called upon to play essential roles in enhancing their production and conservation. In general, a larger global population, together with continuing economic development, should translate into more research and innovation activities. At the same time, research and innovation agendas may be significantly influenced by the multiple development challenges faced by countries with large population growth. New international STI co-operation and agreements – for example, around the UN's SDGs and COP21 Paris Agreement – will seek to accelerate technology transfer to these countries to augment existing channels of diffusion through trade, foreign direct investment (FDI), and the acquisition of capital goods. Developing countries will need to expand and deepen their own research and innovation capabilities if they are to absorb and adapt these technologies for their own needs.

Ageing societies

A combination of low fertility rates and longer life spans will lead to future ageing in all major regions of the world. At current rates, there will be almost global parity between the number of over-60s and the number of children by 2050. This is a significant change from the past and present: while there are around 900 million over-60s in the world today, their number is projected to increase to 1.4 billion by 2030 and 2.1 billion by 2050. Europe is expected to have the largest proportion of over-60s (34% in 2050 compared to 24% in 2015). But rapid ageing will occur in other parts of the world as well, particularly in Asia (UN, 2015a). Almost 80% of the world's older population will live in what are currently less developed regions. The People's Republic of China (hereafter "China") will have about 330 million citizens aged 65 or more, India about 230 million, and Brazil and Indonesia over 50 million by 2050 (UN, 2011). Globally, the number of over-80s is expected to multiply threefold by 2050 (from 125 million in 2015 to 434 million in 2050 and 944 million in 2100). The over-80s group accounted for just 1% of the OECD population in 1950, but its share rose to 4% in 2010 and is projected to be close to 10% by 2050.

Ageing implies changes in lifestyle and consumption patterns, and this will have significant implications for the types of products and services in demand. New markets will emerge as part of a flourishing "silver economy" (OECD, 2014a), while more traditional ones may have to adapt or will even disappear, all of which will have implications for innovation. At the same time, ageing societies could see slower economic growth. High old-age dependency ratios, together with more prevalent non-communicable diseases and increased disability among the elderly, will place considerable burdens on healthcare and other services. The resulting fiscal pressures could draw public spending away from other areas, including STI. Ageing-related illnesses, including cancer and dementia, may also increasingly dominate health research agendas. As the world grows older together, including many emerging economies, international research co-operation on tackling age-related diseases could intensify.

International migration

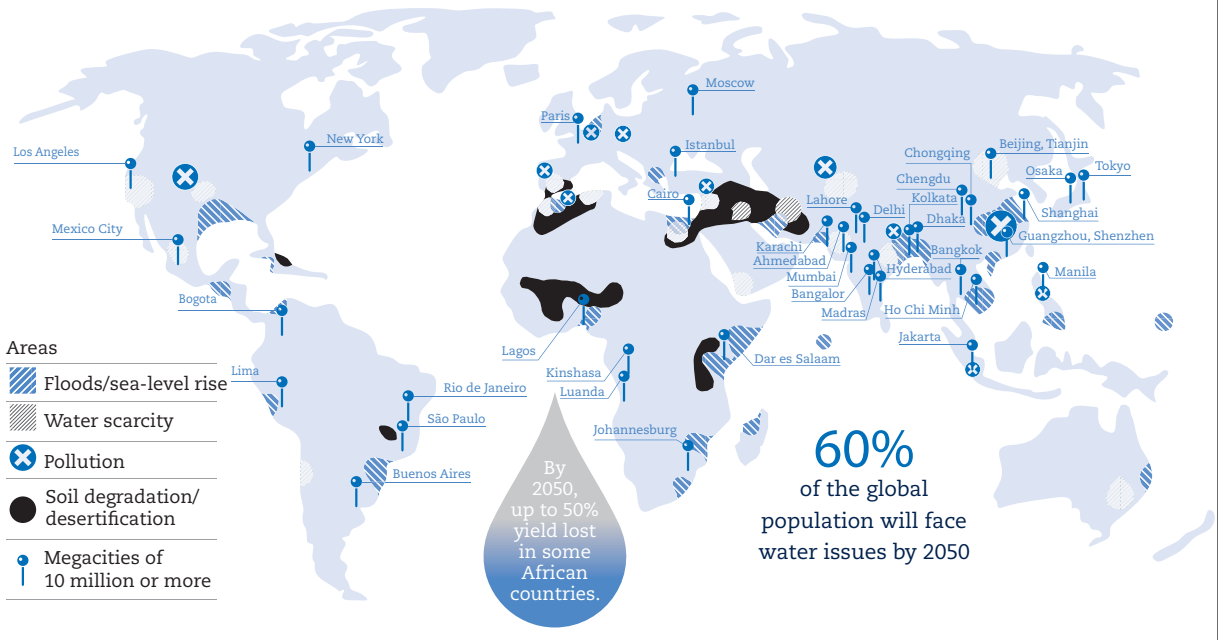
The smaller proportion of working-age people in the population will affect the labour market for STI skills in many OECD countries. The size of the working-age population (15-64) is currently at an historical peak and will very soon begin to diminish. This means the size of the dependent population (currently defined as younger than 15 and older than 64) relative to the working-age population that provides social and economic support will increase. While the ability of elderly citizens to remain active and continue working beyond official retirement age is set to increase, this alone is expected to be insufficient to meet workforce shortages. However, estimations of future workforce shortages should also consider technological change as an important determining factor, particularly the impacts of robotics and artificial intelligence. Though much debated, these technologies may reduce the demand for labour and help balance future skills mismatch. Such technologies and others (e.g. neurotechnologies) may also enhance physical and cognitive capacities, allowing people to work longer in their lives.

International migration may help reduce anticipated labour and skills shortages in receiving countries. The central scenario in the OECD's long-term growth projection assumes that inflows of migrant workers will be an important factor to mitigate ageing in most OECD countries (Westmore, 2014). All the signs point to a further strengthening of factors pushing and pulling migratory flows in the decades to come. Youth bulges in some parts of the developing world are creating conditions ripe for outward migration: a likely lack of employment opportunities and growing risks of internal conflict will force many to seek better lives and safety elsewhere. Climate change may also have more of an influence on future international migration flows (European Environment Agency, 2015).

Many migrants bring qualifications and skills with them. There were 31 million highly educated migrants in OECD countries in 2011, and high-skilled migration increased by 72% over the previous decade (OECD, 2015a). In Europe, over the past decade, new immigrants represented 15% of entries into strongly growing occupations, such as science, technology and engineering as well as the health and education professions. In the United States, the equivalent figure is 22% (OECD and EC, 2014). However, migrants' skills are not fully utilised in the labour markets of destination countries, and close to 8 million migrants with tertiary education in OECD countries are working in low- and medium-skilled jobs (OECD, 2015a). This is also a loss to origin countries facing "brain drain", particularly developing ones, and compromises their ability to develop the indigenous research and innovation capabilities needed to address their development challenges. A further concern is the growing size and importance of ethnic minority communities in destination countries, some of which may be poorly integrated and economically disadvantaged, which could give rise to tensions and instability (OECD, 2016a).

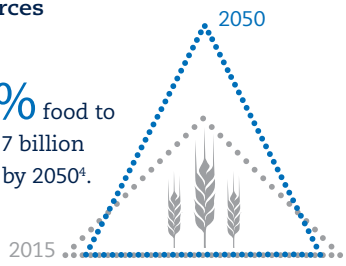
Natural resources and energy

Areas of floods, water stress, pollution and droughts today, and locations of megacities in 2030[1,2]



Growing tensions on water-food-land resources

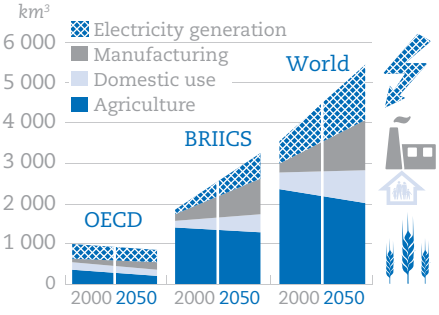
52% of agricultural land is already affected by moderate to severe degradation[3].



+60% food to feed 9.7 billion people by 2050[4].

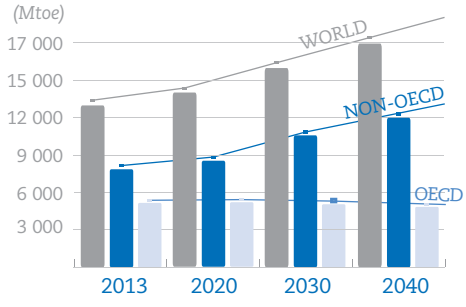
GLOBAL DEMAND

+55% water demand by 2050[5].

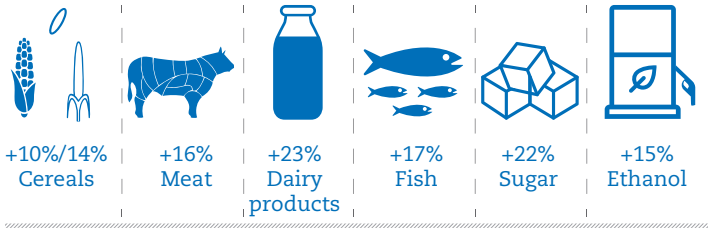


Economic growth in non-OECD will drive further increases in global energy consumption. Asia will account for around 60% of the total increase[6].

+37% increase in global energy demand by 2040[6].

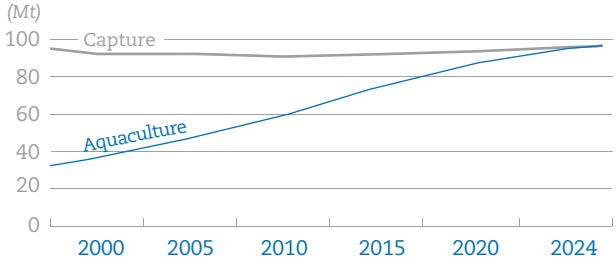


Agricultural production outlook in 2025[7]



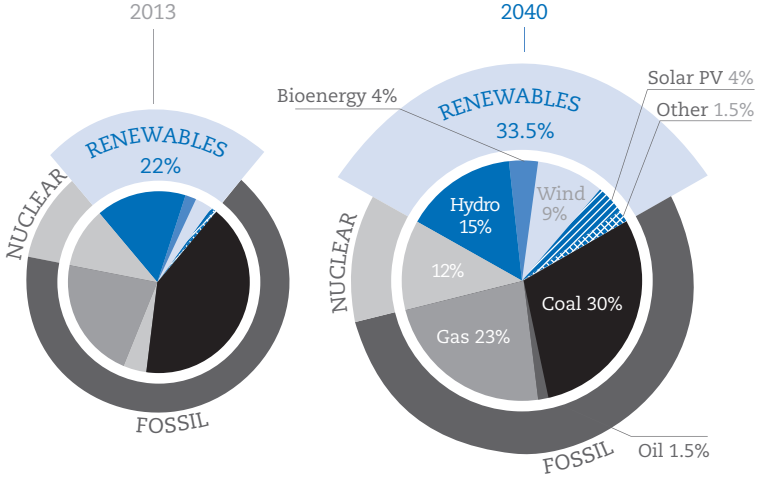
Price increases for most agricultural commodities will likely affect the poorest populations the most.

Aquaculture driving the expansion of global fish supply[7]



South and East Asian countries will continue dominating overall aquaculture production, with China, India, Indonesia and Viet Nam accounting for the majority of projected growth.

New markets for renewables
Energy supply mix (% of electricity generation)[8]



The promise of innovation

- New STI knowledge could improve the monitoring, management and productivity of natural resources and, ultimately, decouple economic growth from their depletion.
- Technology diffusion efforts will be as important as developing new technologies and should promote wide adoption of best available technologies for efficient resource use.

Agriculture, food and water

- In agriculture, as in other sectors, innovation is the main driver of productivity growth. New innovative agricultural technologies and methods could help increase land productivity in a more sustainable way.
- New technologies will play a central role in adapting agricultural practices to climate change and more extreme weather-related conditions.
- Improvements in irrigation technologies and new agricultural practices should help better monitor water use and slow groundwater depletion.
- A new generation of wastewater treatment plants using advanced technologies will be needed to deal with the challenge of micro-pollutants from medicines, cosmetics, etc.

Energy

- Onshore wind and solar photovoltaics are ready to be mainstreamed, but high levels of deployment will require further innovation in energy storage and smart grid infrastructure to increase their adaptability to weather variability.
- The Internet of Things and advanced energy storage technologies offer opportunities to better monitor and manage energy systems. Cities could play a leading role in deploying these smart innovative approaches.

Sources: 1. FAO (United Nations Food and Agricultural Organization) (2015). By 2050, up to 50% yield lost in some African countries if no significant improvement is achieved in production practices.; 2. UNDESA (2015b); 3. UNCCD (2014); 4. FAO (2012); 5. OECD (2012a); 6. IEA (2015a); 7. OECD/FAO (2016b). Cereals include wheat (10%), rice (13%), and maize (14%).; 8. IEA (2015a).

Natural resources and energy

Natural resources are a major – if not the primary – foundation of economic activity and thus ultimately of human welfare. Water, air, land and soil provide food, raw materials and energy carriers to support socio-economic activities. Their extraction and consumption affects the quality of life and well-being of current and future generations. Their efficient management and sustainable use are key to economic growth and environmental quality (OECD, 2014b).

Future population growth, changing lifestyles and economic development will enlarge global demand for water, food and energy and increase pressures on natural resources. Agriculture will remain the largest consumer of water, affecting the quality of surface and groundwater through the release of nutrients and micro-pollutants. Several energy sources change the quality and quantity of water available (e.g. hydraulic fracturing, hydropower, and cooling techniques for thermal and nuclear power plants), so that future shifts in the energy mix have to factor in water management as well (OECD, 2012a). The growing demand for biofuels has raised competition on arable yields. Further reallocation of productive lands towards non-alimentary production will be driven by price volatility and relative profitability of food commodities but could challenge food security in the medium term.

Developments in STI are set to bring new knowledge, innovative solutions and enhanced infrastructures to improve monitoring, management and productivity of natural assets and, ultimately, to decouple economic growth from their depletion. Governments are expected to play significant roles, providing knowledge infrastructures (e.g. databanks, centres of technology convergence), sharing knowledge and best practices, and financing research on agriculture, energy and natural resource management.

Water

Severe water stress is likely in many parts of the world, as water demand has outpaced population growth during the last century (OECD, 2012a; 2014b). If current socio-economic trends continue and no new water management policies are implemented (a baseline scenario), water demand is projected to increase by 55% globally between 2000 and 2050. The sharpest increases are expected from manufacturing (+400%), electricity generation (+140%) and domestic use (+130%).

Groundwater is by far the largest freshwater resource on Earth (excluding water stored as ice), representing over 90% of the world's resource (UNEP, 2008; Boswinkel, 2000, cited in OECD, 2012a; OECD, 2015b). In areas with limited surface water supply, such as regions of Africa, it is a relatively clean, reliable and cost-effective resource. Yet, groundwater is being exploited faster than it can be replenished in many parts of the world. Its rapid depletion is a consequence of the explosive spread of small pump irrigation throughout the developing world. Such intensive groundwater use is not confined to the developing world, however, with the volume of groundwater used by irrigators in several OECD countries also substantially above recharge rates, e.g. in some regions of Greece, Italy, Mexico and the United States, undermining the economic viability of farming (OECD, 2012a). Improvements in irrigation technologies and the introduction of new agricultural practices and robotics in agriculture could help better monitor water use and slow groundwater depletion, though will need to be coupled with wider institutional changes to be effective (OECD, 2015b).

Surface and groundwater are also becoming increasingly polluted because of nutrient flows from agriculture and poor wastewater treatment. Surpluses of nitrogen in agriculture

are projected to decrease in most OECD countries by 2050 with greater efficiency of fertiliser use. The trend is, however, expected to go in the opposite direction in China, India and most developing countries. In parallel, nutrient effluents from wastewater are projected to increase rapidly due to population growth, rapid urbanisation and the growing number of households connected to sanitation and sewage systems. The nutrient removal in wastewater treatment systems is also expected to improve rapidly, but not fast enough to counterbalance the projected rise in inflows. Micro-pollutants (e.g. medicines, cosmetics, cleaning agents, and herbicides) are particularly worrying because they enter water bodies of various types (urban drainage, agriculture, rainwater runoff), have negative and cumulative effects on organisms (e.g. interference with hormone systems, cancers, births defects) and are resistant to regular treatment technologies.

The consequences of degraded water quality will be increased eutrophication, biodiversity loss and disease (OECD, 2012a). The economic costs of treating water to meet drinking water standards are also significant in some OECD countries. Eutrophication of marine waters imposes high economic costs on commercial fisheries for some countries (e.g. Korea and the United States) (OECD, 2012a). Advances in synthetic biology, for instance, for crop genetics, and improved efficiency in water sanitation, will require more R&D and the implementation of new generations of wastewater treatment plants and sanitation and sewage systems, combining the use of sensors and nanotechnologies (see Chapter 2). Tapping alternative water sources, such as rain and storm water, used water, and desalinated sea, and encouraging successive uses of water to alleviate scarcity are also emerging innovative practices.

Water is likely to become a major political issue. Over 40% of the world's population (3.9 billion people) is likely to live in river basins under severe water stress by 2050, but, at the same time, almost 20% (1.6 billion) are projected to be at risk from floods. Most of the future growth in water demand will arise from developing countries where the degradation of environmental conditions is already well-advanced. By contrast, water demand across the OECD area is expected to fall in line with efficiency improvements in agriculture and investments in wastewater treatment (OECD, 2012a).

Food

Global food and agriculture systems face multiple challenges. More food must be produced for a growing and more affluent population that demands a more diverse diet. At the same time, competition for alternative uses of natural resources is increasing and agricultural practices and technologies will have to adapt to climate change and more extreme weather-related conditions.

It is estimated that 60% more food will be required to feed the world population by 2050 (OECD, 2013a). On a global level, food production should be able to support this demand and the proportion of people who are undernourished should drop slightly from 11% to 8% by 2025 (OECD/FAO, 2016). However, food and nutritional insecurity will persist in many, predominantly poor, regions where water scarcity and soil degradation will continue to damage agricultural lands (FAO and WWC, 2015). Today, around half of arable land is already affected by moderate to severe degradation. Desertification and drought are likely to transform around 12 million hectares of productive lands (the equivalent of Bulgaria, Honduras, or Nicaragua) into barren regions annually (UN, 2015b). If no significant improvements are achieved in production practices, the loss of yield may be as high as 50% in some African countries by 2050 (UNCCD, 2014). The situation in most OECD

and BRIICS countries is, however, less severe, as continuing yield improvements will lead to more efficient use of land. Instead of agricultural land expansion, land abandonment is planned in many countries, which will allow ecosystems to partially recover and regenerate (OECD, 2012a).

Modern agricultural technologies and methods could help increase land productivity in a more sustainable way. In agriculture, as in other sectors, innovation is the main driver of productivity growth (OECD, 2013b). Innovation can also improve the environmental performance of farms and the quality of agricultural products. Sensors can help farmers manage their tractor fleet, reducing downtime and saving energy (OECD, 2016b). Some innovations (e.g. around irrigation, animal medicines, pesticides, improved seeds, and innovative risk management tools) have the potential to help farmers better deal with production and income uncertainties, and ultimately increase earnings. For instance, increased production, together with innovation in aquaculture, has significantly lowered production costs in fisheries, providing benefits to both consumers and producers (OECD, 2015c). In some regions, the challenge is to adapt agricultural production systems to more difficult natural environments, e.g. due to salinity, more frequent drought, etc.

Food consumption habits will likely change, reflecting growing living standards, higher participation rates of women in the labour force, and reduced time available for meals (OECD, 2013b). The prices of most agricultural commodities are projected to increase significantly by 2050, which will especially affect poorer populations (Ignaciuk and Mason-D'Croz, 2014). Innovation will have a key role to play in helping the agrifood sector produce more nutritious, diverse and abundant food, address changes in food diets, and provide raw materials for non-food use. At the same time, innovation should alleviate natural resource depletion and enable adaptation to the expected changes in natural conditions caused by climate change (OECD, 2013b).

Aquaculture will continue to be one of the fastest growing food sectors and, in 2025, is expected to provide over half the fish consumed worldwide. Fish consumption will expand in all continents, but particularly in Oceania and Asia, and South and East Asian countries, predominantly China, India, Indonesia and Viet Nam, which are projected to dominate production (OECD/FAO, 2016).

Energy

Energy consumption will rise sharply, driven by population and economic growth. Based on existing and planned government policies (the International Energy Agency's [IEA] so-called "New Policies Scenario"), global primary energy demand is set to increase by 37% between 2012 and 2040. Most of this increased demand can be ascribed to economic growth in OECD partner economies, particularly in Asia, which will account for around 60% of global energy consumption (IEA, 2015a). Growth in global demand is expected to slow down after 2025 as a result of price and policy effects, and structural shifts towards services and lighter industrial sectors (IEA, 2014a). However, industry will likely remain the largest consumer of energy in 2040, followed by transportation and commercial and residential buildings.

The global energy mix will be transformed, mainly on account of the growing use of renewables. This means that low-carbon sources and fossil energies (i.e. oil, gas and coal) will make up almost-equal parts in the world's energy supply mix by 2040. Worldwide, the largest share of growth in use of renewables for electricity generation will be from wind power (34%), followed by hydropower (30%) and solar technologies (18%) (IEA, 2014a). At the

same time, biofuels may provide up to 27% of the world's transportation fuel by 2050, up from the current level of 2% (IEA, 2011). New markets for renewables will depend on technological breakthroughs and smart infrastructures, enabled by significant investments in R&D and infrastructures and new strategic public-private partnerships (IEA, 2014b).

The water-food-energy nexus

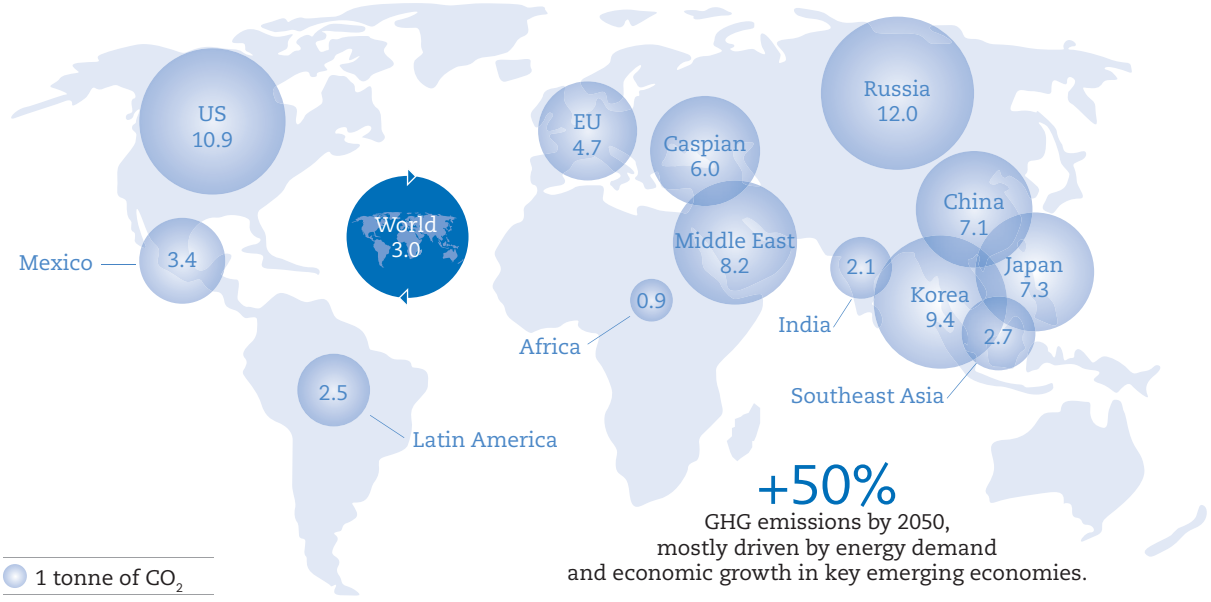
The interconnection of water-food-energy issues and their interdependence make them difficult to address separately. The Internet of Things (IoT), smart apps, sensors, machine-to-machine communication, and the greater connectivity of people and objects offer opportunities to better monitor pressures on the water-food-energy nexus, anticipate critical tensions and balance supply and demand (see Chapter 2). Cities are the places at which these smart innovative approaches could arise and be efficiently deployed (OECD, 2014c).

The nexus among water, food and energy (and environment) is close, complex, and challenging. Policy coherence and a co-ordinated approach among water, agriculture and energy policies, as well as other sectoral policies – particularly transport, industry and construction – will be essential. Smart regulation will be required to regulate natural resources consumption (e.g. water extraction licenses) and put sustainable prices on natural resources and related services as a way to signal scarcity and manage demand. International co-operation on R&D, on resource management and for aligning national policy frameworks will be needed.

Climate change and environment

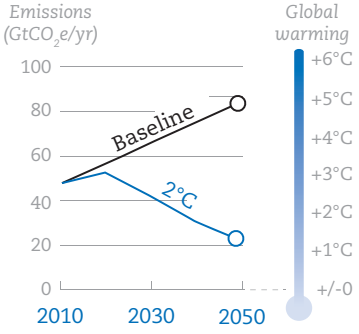
Energy-related CO_2 emissions per capita, 2030

CO_2 emissions account for 75% of global GHG emissions, with most coming from energy production[1]



+50%
GHG emissions by 2050,
mostly driven by energy demand
and economic growth in key emerging economies.

Global emissions and the 2°C target[2]

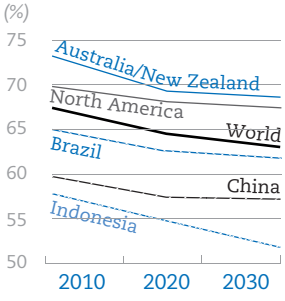


40%-70% reductions in global GHG emissions by 2050 to meet the 2°C Scenario[3].

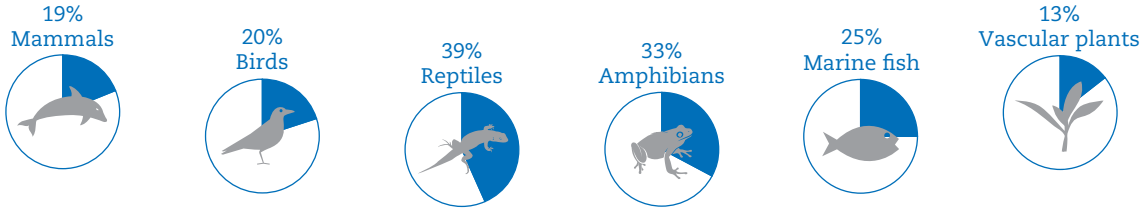
10%
Biodiversity loss by 2050, with highest losses in Asia, Europe and southern Africa[4].

60%
of the world's biocapacity is held by only ten countries that suffer most from heavy land and forest degradation[5].

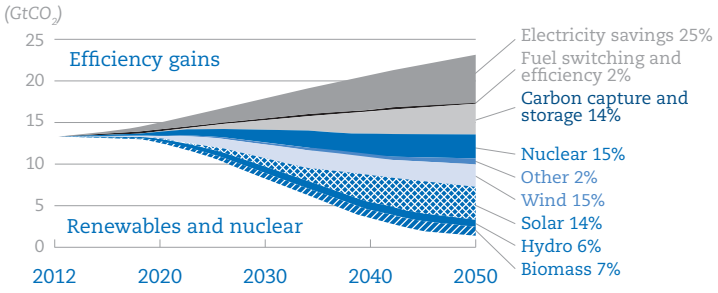
Terrestrial biodiversity loss[4]



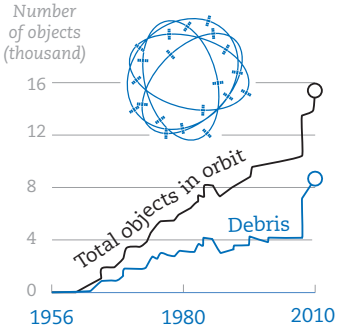
OECD biodiversity is at threat
% of threatened species[5]



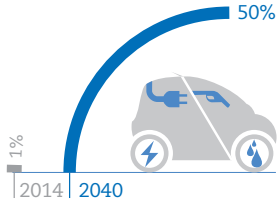
Key technologies to reduce power sector CO_2 emissions[6]



Space junk: danger of collision[7]

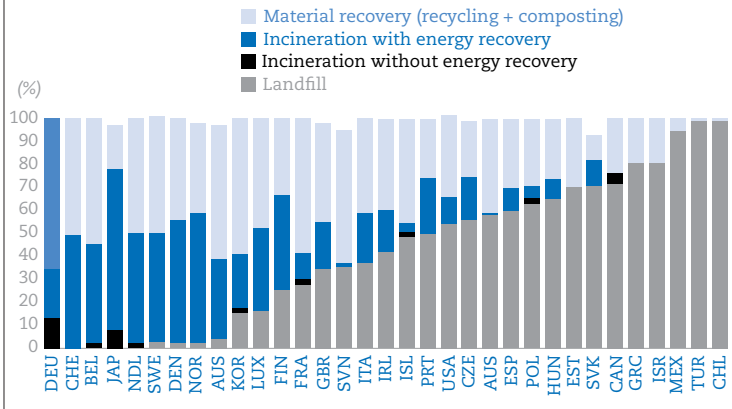


Exploding sales of hybrid vehicles
Total vehicle sales in %[8]



Hybrid cars are expected to become cost-competitive by 2025.

Waste disposal: ever more efforts to reduce landfilling[9]



Over the past two decades, OECD countries have put significant efforts into curbing municipal waste generation.

International co-ordination

- The global nature of climate change and environmental degradation will require greater international co-operation on solutions, including research and innovation.
- Climate change mitigation and adaptation will depend on technology transfer to less advanced countries, which are set to account for the largest increases in GHG emissions over the next few decades due to their rapid development.

Research strategies

- Energy technology innovation will be key in achieving the 2 °C scenario. A comprehensive portfolio of low-carbon technologies, including solutions for decarbonisation, will be needed to achieve policy climate goals.
- Challenges of climate change and ongoing degradation of the natural environment, including loss of biodiversity, could become even more dominant themes in future national research agendas.
- The "circular economy" concept will likely gain momentum and shape future innovation agendas. New technologies, processes, services and business models will be fundamental requirements for a circular economy.

Multi-actor perspective

- While governments are expected to play a leading role in enabling the transition to low carbon societies, the private sector will need to lead innovation efforts in this direction.
- The Internet of Things, smart apps and sensors will enable a closer monitoring of climate change, ecosystems and biodiversity.
- Participatory monitoring and big data will generate large amounts of novel data that could support new research practices and citizen science in support of more sustainable growth.

Sources: 1. IEA (2015b). Energy-related CO_2 emissions per capita by selected region in the INDC Scenario and world average in the 450 Scenario. ; 2. UNEP (2015); 3. UNEP (2014); 4. OECD (2012a). Terrestrial mean species abundance (terrestrial MSA) is a relative indicator describing changes of biodiversity with reference to the original state of the intact or pristine ecosystem (i.e. a completely intact ecosystem has a MSA of 100%).; 5. OECD (2016c). OECD figures are simple average of available country shares. However simple average does not reflect cross-country differences, and some species are more threatened in some countries than in others. Species assessed as Critically Endangered (CR), Endangered (EN), or Vulnerable (VU) are referred to as "threatened" species. Reporting the proportion of threatened species on The IUCN Red List is complicated by the fact that not all species groups have been fully evaluated, and also by the fact that some species have so little information available that they can only be assessed as Data Deficient (DD).; 6. OECD and IEA (2015). The 2°C Scenario (2DS) is the main focus of *Energy Technology Perspectives*. It limits the total remaining cumulative energy-related CO_2 emissions between 2015 and 2100 to 1 000 $GtCO_2$.; 7. NASA (29 September 2016); 8. ExxonMobil (2016); 9. OECD (2015d), OECD (2014d), OECD (2014e).

The world is warming

Global land and ocean surface temperature data show an averaged combined warming of 0.85°C over the period 1880 to 2012. The greatest warming over the past century has occurred at high latitudes, with a large portion of the Arctic having experienced warming of more than 2°C. The last 30 years were likely the warmest of the last 1 400 years in the northern hemisphere (IPCC, 2014). Further global warming over the next few decades is now inevitable.

There is a strong relationship between projected global temperature change and cumulative CO_2 emissions (IPCC, 2014). Anthropogenic greenhouse gas (GHG) emissions are extremely likely to have been the dominant cause of the observed warming since the mid-20th century. Atmospheric concentrations of carbon dioxide (CO_2), methane and nitrous oxide are unprecedented in at least the last 800 000 years. CO_2 emissions account for around 75% of global GHG emissions, with most coming from energy production. Around half of the anthropogenic CO_2 emissions since 1750 have occurred in the last 40 years. Fossil fuel combustion represents two-thirds of global CO_2 emissions (OECD, 2012a) while agriculture is a major emitter of the more powerful greenhouse gases of methane and nitrous oxide.

Mitigating global warming requires much more ambitious strategies to reduce GHG emissions. The IEA's New Policies Scenario is consistent with a long-term temperature rise of 4°C. This ambitious scenario requires significant changes in policy and technologies, but will still lead to dangerous levels of climate change. A more stringent scenario (2DS) that would meet the 2°C target agreed at the Paris climate conference requires a 40%-70% reduction in global GHG emissions by 2050. It will mean increasing the share of low-carbon electricity supply from 30% to more than 80% by this time (IPCC, 2014).

Energy technology innovation will be key in achieving the 2DS. A comprehensive portfolio of low-carbon technologies, including solutions for decarbonisation, could make climate goals achievable (IEA, 2015c). Some solutions will be broadly applicable, while others will target specific sectors. In the power sector, onshore wind and solar PV are ready to be mainstreamed. But high levels of deployment will require further innovation in energy storage and smart grid infrastructure to increase their flexibility to weather variability (IEA, 2015c). Carbon capture and storage (CCS) technologies are projected to play an important role, though require further technical and market development before they can be extensively implemented. Nanotechnology can provide innovative solutions for CCS materials (OECD, 2016b). Biotechnology also offers unique solutions to dependence on oil and petrochemicals. Bio-based batteries, artificial photosynthesis and micro-organisms that produce biofuels are some recent breakthroughs that could support a bio-based revolution in energy production.

There are also expanding markets for low-energy products and components and, in sectors such as industry, transport and buildings, energy efficiency technologies are expected to play a leading role. Nanotechnology can provide innovative solutions to lower energy use in industry and enable the replacement of energy-hungry processes with low-cost processes. In addition, low-energy components or technologies could be instrumental to the development and uptake of other technologies. For example, additive manufacturing can support less material and energy use through sophisticated design and lean production principles. This can be achieved by printing replacement parts that would otherwise be discarded; by reducing weight in a vehicle; or by improving a product's energy efficiency. Such energy savings can be quite large, especially in sectors like aerospace.

As emerging economies are projected to account for most of the increase in GHG emissions over the coming decades, their uptake of innovative low-carbon technologies will be crucial – and could account for almost three-quarters of worldwide CO_2 emissions reductions by 2050 in the 2DS. Rapid economic development in these regions will support technological deployment but international co-operation will be required to ensure technology and knowledge transfer. Furthermore, future technology adoption will require raising domestic skills and organisational capabilities (IEA, 2015c).

Consequences for climate, ecosystems and health are dramatic

A series of severe climatic changes will accompany global warming. Heat waves will likely occur more often and last longer, while extreme precipitation events will become more intense and frequent in many regions. Rainfall will most likely increase in the tropics and higher latitudes, but decrease in drier areas. The oceans will continue to warm and acidify, strongly affecting marine ecosystems. The global mean sea level will continue to rise at an even higher rate than during the last four decades. The Arctic region will continue to warm more rapidly than the global mean, leading to further glacier melt and permafrost thawing. However, while the Atlantic Meridional Overturning Circulation will most likely weaken over the 21st century, an abrupt transition or collapse is not expected (IPCC, 2014).

Climate change will have profound impacts on water and food security at regional and global levels. Extreme and variable rainfall will affect water availability and supply, food security, and agricultural incomes, and will lead to shifts in the production areas of food and non-food crops around the world (IPCC, 2014). The impacts of climate change will likely reduce renewable surface water and groundwater resources in the driest regions, intensifying competition for water among different sectors (IPCC, 2014).

As climate change modifies water-food systems and the quality of air, new diseases could appear or existing ones expand. Global premature deaths from outdoor air pollution are set to double by 2050 (OECD, 2012a). Malaria is the most important infectious disease that is exacerbated by climate change. Currently, more than half of the world's population (3.7 billion) lives in areas at risk. This number is expected to grow to 5.7 billion people by 2050. The bulk of the population living in risk areas (i.e. warm areas which are a suitable habitat for the malaria mosquito) will be in Asia (3.2 billion) and Africa (1.6 billion).

The number of weather-related disasters has increased worldwide over the last three decades, particularly floods, droughts and storms (EMDAT data, cited in OECD, 2012a). Science and technology will play a vital role in monitoring ecosystems and managing natural disasters. National meteorological agencies that are often in charge of early warning systems will increasingly rely on satellite data, in addition to ground-based networks of radars, to maintain continuous observation of global weather, making warning systems more efficient (OECD, 2012c). In particular, the deployment of constellations of nano- and microsatellites could support a continuous monitoring of wider geographic areas, including oceans, and improvements in forecasting (see Chapter 2). Construction and transport industries will draw on innovative materials and technologies to adapt to new extreme environmental conditions.

Global biodiversity is at threat

Changes in temperature and precipitation regimes influence the distribution of species and ecosystems. As temperatures increase, ecosystems and species' ranges tend to shift towards the poles or to higher altitudes (OECD, 2012a). This migration causes some

ecosystems to shrink and others to expand. Biodiversity loss is a major environmental challenge. Despite some local successes, biodiversity is on the decline globally and this loss is projected to continue (OECD, 2012a). Around 20% of mammals and birds, almost 40% of reptiles, a third of amphibians, and a quarter of marine fish are already on the list of threatened species (OECD, 2016c). In a baseline scenario, i.e. in the absence of new policy interventions, 10% of biodiversity is likely to be lost by 2050, most of the loss occurring before 2030. The steeping declines are likely to be in the bush and savannah, as well as temperate and tropical forests (OECD, 2012a).

Threat levels are particularly high in countries with high population density and a high concentration of human activities. Pressures on biodiversity can be physical (e.g. habitat alteration and fragmentation), chemical (e.g. toxic contamination, acidification, oil spill, other pollution) or biological (e.g. alteration of species dynamics and structure through the release of exotic species or the commercial use of wildlife resources) (OECD, 2015e). But, to date, the main drivers of global terrestrial biodiversity loss have been land-use change and management, i.e. conversion of natural ecosystems for producing food and bioenergy crops and livestock (OECD, 2012a). Deforestation remains a major concern, although annual deforestation rates are slowing down. Over-exploitation of water resources and changes in the hydromorphology of water systems (eutrophication, acidification) threat aquatic ecosystems.

Yet, the large benefits of biodiversity and ecosystem services provide incentives to investing in conservation and sustainable use. For example, some estimates give pollination services provided by insects at USD 192 billion per year and the global value of coral reefs for fisheries, coastal protection, tourism and biodiversity at USD 30 billion per year. The global loss of forests that provide natural habitats and contribute to carbon sequestration, water regulation and erosion prevention, is estimated at between USD 2 trillion and USD 5 trillion per year (examples cited in OECD, 2012a). In some countries, in Asia and Africa, 80% of the population relies on traditional medicine (including herbal medicine) for primary health care (OECD, 2014f). As extinctions continue the availability of some of these medicines are likely to be reduced and new drug developments may be curtailed.

Most biodiversity-rich areas are located in developing countries. Low-income countries are expected to account for 39% of global terrestrial biodiversity losses, the BRIICS 36% and OECD countries 25% by 2050 (OECD, 2012a). Losses are likely to be high in Japan and Korea, Europe, Southern Africa and Indonesia. Some central European countries already experience extreme biodiversity threat (OECD, 2016c). In addition developing countries tend to bear most of the costs of biodiversity loss as they are often more dependent on natural resources for economic development than developed countries (OECD, 2012a).

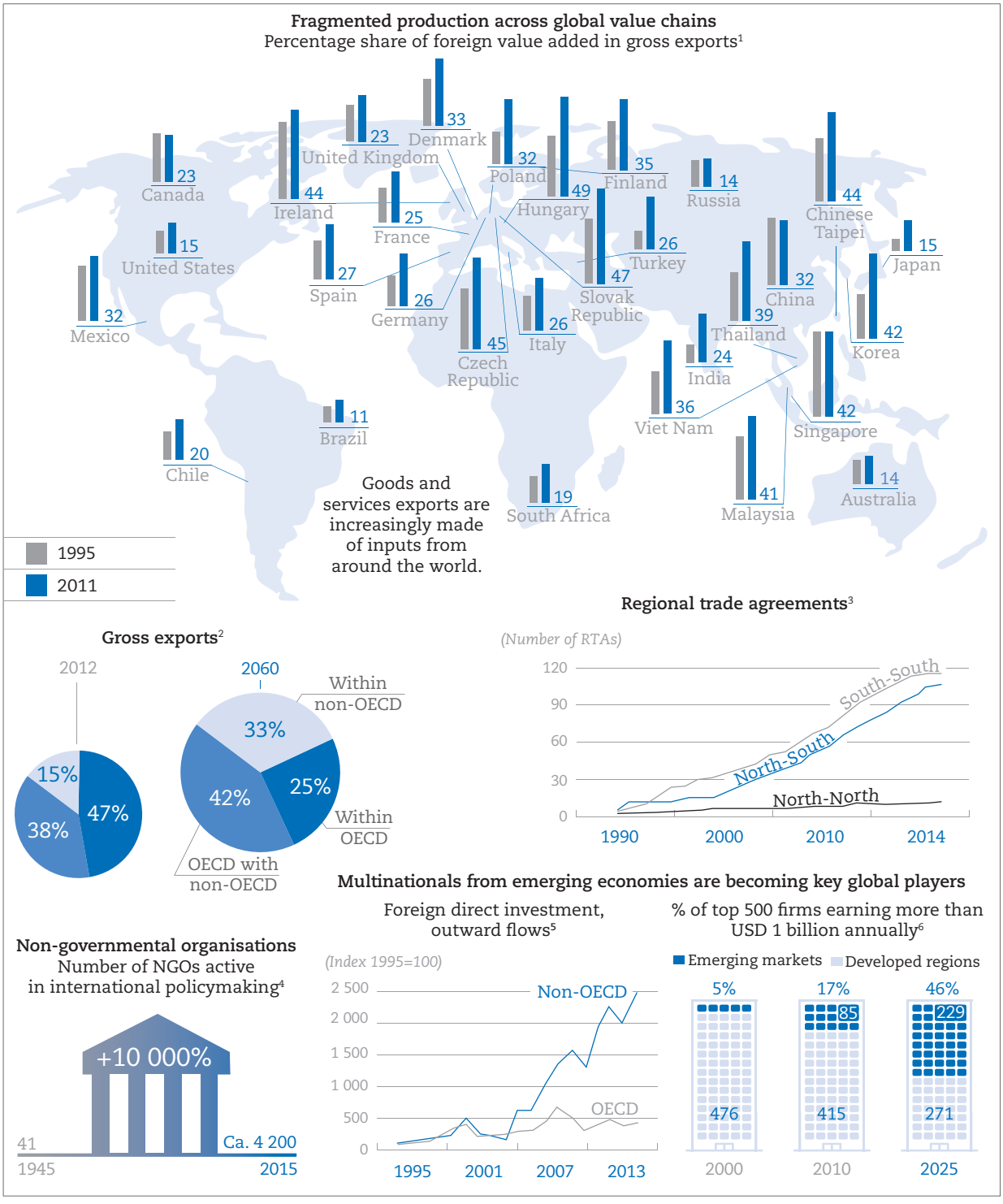
Governments have tried to design networks of protected areas connected by natural corridors with a view to restoring, maintaining and enhancing ecological coherence and the natural adaptive capacity of ecosystems. Where ecosystems span political boundaries, maintaining connectivity may require co-ordination among managers and scientists from neighbouring countries. Local and indigenous communities can also play a critical role in the management of protected areas and as a source of local and traditional knowledge (OECD, 2012a). The IoT, smart apps and sensors could support the functioning of these protected areas and help involve local populations and populations in remote areas in a closer monitoring of ecosystems and biodiversity. Participatory monitoring and big data could generate large amounts of novel data and support new research practices and citizen science.

Waste recycling and the premises of the circular economy

Weak waste management has negative impacts on human health and the environment, e.g. soil and water contamination, air quality, land use and landscape. Over the past two decades, OECD countries have put significant efforts into curbing waste generation and the growth of municipal waste has slowed from 1.24% between 1995 and 2004 to 0% between 2005 and 2014 (OECD, 2015e). Today, a person living in the OECD area generates on average 520 kg of waste per year. Increasing amounts of waste are being fed back into the economy through recycling. Mechanical and biological pre-treatment is increasingly used to enhance recovery rates and incineration efficiency. Government guidelines encourage or require manufacturers to accept responsibility for their products after the point of sale, e.g. the European Union has introduced recycling targets for all its member states. Landfilling of municipal waste has been banned in a few countries. Recycling rates are increasing (by up to 80% in some cases) for materials such as glass, steel, aluminium, paper and plastics (OECD, 2015f).

A perceptible shift is under way towards the "circular economy". OECD countries are stepping up efforts to move to a more resource-efficient economy, and are showing signs of decoupling material consumption from economic growth. The circular economy implies a systemic change, moving to a zero- or at least low-waste, resource-efficient society and involving big changes to our methods of both production and consumption. Looking beyond the potential for materials savings and a smaller footprint on the environment that a move away from the established "take, make and dispose" model could bring, a circular economy would create huge economic opportunities as new services and business models emerge and the relationship between producer and consumer, and between a product and its user, undergoes radical transformation. Repair, re-use, re-distribution and re-manufacture would increase, as would recycling rates; and materials technology would evolve and enable a move from non-renewable materials to the production and use of high levels of renewable materials in finished products (Waste Management World, 2015). This scaling up of the shift to a circular economy promises to deliver substantial macroeconomic as well as corporate benefits. The materials savings potential alone is thought to be over USD 1 trillion annually (WEF, 2014; McKinsey Centre for Business and Environment and The Ellen MacArthur Foundation, 2015).

Globalisation

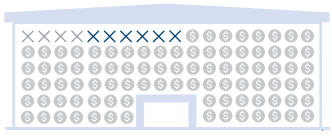


Crime is increasingly globalised
Value of illicit international trade (estimates, USD billion, 2015)[7]

Illicit trade is a multi-billion-dollar business.

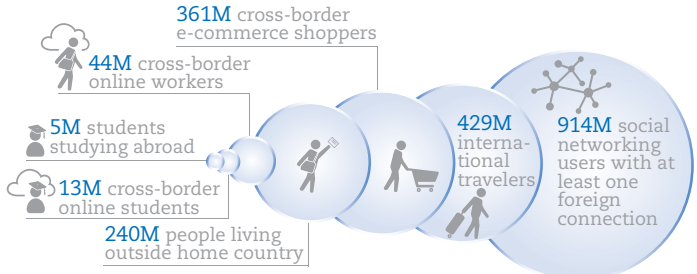
Tax evasion has turned global
Tax revenue losses (estimates, USD billion, 2015)[8]

USD 100-240 billion could be lost annually due to tax avoidance…



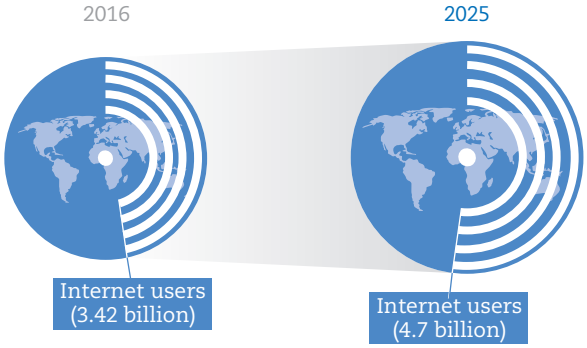
… This is 4% to 10% of global corporate income tax revenues.

Individuals participating in globalisation today[9]



By 2020, some 940 million (M) online shoppers are expected to spend almost USD 1 trillion on cross-border e-commerce transactions.

Internet users, 2016-25[10]



English is the lingua franca of the globalised world with 1 in 4 people using it globally. Non-native speakers account for more than 80% of English online communications[11].

International R&D co-operation

- Globalisation will continue to facilitate the wide diffusion of knowledge, technologies and new business practices and will itself be deepened by this diffusion.
- National STI policy could be framed increasingly in global terms, reflecting the global nature of many problems and issues, and the globalisation of markets and production.
- International agreements and initiatives, such as the Paris Agreement on climate change (COP21) and the UN's Sustainable Development Goals, will further international co-operation in research and direct it towards global grand challenges.

Business R&D

- Business R&D and innovation are increasingly global.
- As important agents of globalisation, multinational enterprises could internationalise their R&D at a faster pace and on a larger scale than before.
- Global value chains could further encourage national industrial specialisation and an increasing concentration of innovation capacities.
- Standards play a crucial role in innovation and are increasingly internationalised since, in a globalised economy, compatibility and interface across borders are ever more important.

Human mobility

- International mobility of highly educated individuals at different stages of their professional careers is a significant driver of knowledge circulation worldwide.
- Countries and institutions are engaged in a global competition for talent to build their own centres of global scientific excellence.
- Digital technologies increasingly help ease the strains of mobility, enabling individuals to maintain regular contact with friends and families for example.

Sources: 1. OECD and WTO (2016); 2. Johansson and Olaberría (2014a); 3. WTO (2013); 4. UN ECOSOC (2016). Figures are cumulative. The cut-off date for these data is 8 January 2015.; 5. OECD (2015f); 6. McKinsey & Company (2016); 7. OECD (2016d); 8. OECD and G20 (2016). BEPS refers to tax avoidance strategies that exploit gaps and mismatches in tax rules to artificially shift profits to low or no-tax locations. Under the inclusive framework, over 100 countries and jurisdictions are collaborating to implement the BEPS measures and tackle BEPS.; 9. Facebook, AliResearch, US Department of Commerce, OECD, World Bank, MGI (2016); 10. Burt, D. (2014); 11. Sharifian, F. (2013).

Globalisation

Globalisation – in the form of international flows of capital, goods, and people – facilitates the spread of knowledge, technologies and new business practices. These dynamics positively affect innovation and long-term economic productivity. Furthermore, technological change, particularly in ICTs and transport, has enabled and even accelerated globalisation. The megatrend of ever more globalisation may continue to exert significant influence over the next 10-15 years, though counter-currents, such as growing protectionism, may be disruptive and give rise to discontinuity.

Trade and global value chains

Since 1995, most countries have experienced significant increases in the share of foreign value added in both exports and final consumption, reflecting the increasing interdependency of the global economy (OECD, 2015g). Global trade integration is expected to continue to grow in the future, albeit at a slightly slower rate than seen during recent decades. Trade in services is expected to continue to expand faster than trade in goods, due partly to the continuing liberalisation of the sector, partly to the increasing share of GDP accounted for by services, and partly to trends in consumption pushed by ageing populations. Trade patterns will reflect shifts in global economic weight, with exports from OECD non-member economies expected to rise from 35% of world exports in 2012 to 56% in 2060 (Braconier, Nicoletti and Westmore, 2014).

The rapid growth of global value chains (GVCs) has been an important driver of economic globalisation during the past decades and has resulted in a growing interconnectedness between countries. GVCs have on average become longer and more complex over time with production spanning a growing number of countries, increasingly also in emerging economies. The increasing international fragmentation of production in GVCs, assisted by digitally-enabled logistics, telecommunications, and business services, have seen more labour-intensive activities typically offshored from OECD countries to economies with low-cost labour. But the extent to which this will continue in the future is uncertain. Wage increases, e.g. in eastern China, and increasing automation are eroding the labour cost advantage of emerging economies, while long and complex GVCs have exposed companies to a growing degree of supply risk in case of adverse shocks. In addition, management, logistical and operational problems, including the protection of IPR, resulted often in significant "hidden" costs (i.e. costs that were not taken into account in the decision to offshore) and have in some cases made offshoring less or not profitable (OECD, 2015h). Taken together, these supply-side factors may motivate some companies in some industries to "re-shore" activities closer to their main markets in OECD countries.

At the same time, emerging economies like China are attempting to switch to higher value-added activities, and shift their positions – both upstream and downstream – in GVCs. Innovation is the key to capacity upgrading. Industrial R&D capacities have developed fast in these regions, and steady increases in R&D intensities point to growing global competition in R&D assets. More broadly, the growing importance of GVCs might result in stronger concentration on a specific set of tasks, i.e. those in which a country's firms have a comparative advantage. Depending on the governance structures of GVCs, this can lead to an increasing concentration of innovation capacities among national actors (OECD, 2015i).

In addition to moves to foster more open multilateral trade over the last few decades, many countries have more recently sought in parallel to establish new bilateral and

regional trade agreements (RTAs) to increase trade and spur economic growth. The current proliferation of RTAs in part reflects a demand for deeper integration than has been achieved by existing multilateral agreements. These agreements could see the geography of GVCs accordingly shift towards a more regional organisation.

Multinational enterprises

R&D and innovation activities are increasingly global, thanks to the shifting international organisation of functions within multinational enterprises (MNEs), which are internationalising their R&D at a faster pace and on a larger scale than before (OECD, 2015i). Foreign-controlled affiliates play an important role in domestic R&D in several OECD countries. In 2013, they accounted for more than one-fifth of total business R&D among a majority of countries for which data are available (OECD, 2015g). Patented inventions also often result from collaboration between inventors from different economies. On average, the international co-invention of patents increased by 27% between 2000-03 and 2010-13 (OECD, 2015g).

FDI flows worldwide have tripled since the mid-1990s, growing at a faster pace than international trade in goods and services. Although most flows still take place within the OECD, the landscape has changed dramatically in the past decade. Until 2003, around 95% of FDI outflows originated from OECD countries, but over the past decade their share has fallen below 80% owing to the spectacular rise in overseas investment by emerging economies. Overall, outward flows from BRIICS have more than tripled between 2002-07 and 2008-13. Some of this investment has been directed at acquiring more advanced technologies than those available domestically as part of corporate technology upgrading strategies, a phenomenon that is likely to grow as emerging economies move closer to technological frontiers in certain sectors. As for inward flows, FDI in China and Southeast Asia has risen from an average of about USD 83 billion a year in 1995-2001 to about USD 417 billion a year in 2008-13. China was the largest non-OECD FDI recipient in 2013, with a twofold increase in average annual inflows over 2008-13. Inward FDI may provide recipient countries with access to new technologies and generate employment opportunities and knowledge spillovers for domestic firms (OECD, 2015g).

Standards play an important role in innovation, providing industry-wide consensus on the rules, practices, metrics or conventions used in technology, trade and society at large. Standardisation work is increasingly conducted internationally, since, in a globalised economy, compatibility and interface across borders are increasingly important. Firms that play primary roles in setting international standards gain advantages from doing so, to the extent that the new standards align with their own standards and/or features of their productive base (OECD, 2015i).

Global digital flows

Not only have flows of goods and finance increased over the last two decades, but digital flows of commerce, information, searches, video, communication, and intracompany traffic have surged as well. Cross-border bandwidth has grown 45 times larger since 2005 and is projected to grow by another nine times in the next five years (MGI, 2016). Global digital platforms are helping drive down costs of cross-border communications and transactions, thereby reducing the minimum scale at which businesses can operate globally and enabling small businesses to become “micro-multinationals” (eBay, n.d.). Global digital platforms also help individuals form their own cross-border connections, enabling them to learn, find work,

showcase their talent, and build personal networks. Some 900 million people have international connections on social media, and 360 million take part in cross-border e-commerce, figures that are growing rapidly (MGI, 2016).

Globalisation of illicit trade

The liberalisation of trade and relatively low cost of transcontinental supply chains have changed the geographic scope, volume and range of goods traded in illegal markets. The profits of transnational organised crime have been estimated to be as high as USD 870 billion, equivalent to 1.5% of global GDP (UNODC, 2011). The magnitude and gravity of their negative social, economic and even political impacts have also grown (OECD/EUIPO, 2016). For example, international trafficking in narcotics, arms and especially humans have obviously corrosive social effects. Illicit trade in counterfeits undermines the model of investment in research and development, e.g. in pharmaceuticals. Wildlife trafficking destroys biodiversity and can trigger the spread of zoonotic disease. Illicit trade's use of bribery and undue influence also undermines good governance and can threaten political stability (OECD, 2016d).

International illicit networks depend on and benefit from many of the same technologies and innovations that legal private firms exploit to enhance their competitiveness. The Internet is a particularly prominent example, with the migration of criminal activities online increasing the overall digital security threat level. An underground cybercrime economy has emerged, with well-organised transnational groups demonstrating considerable technical innovation skills to commit financial, information and identity theft using increasingly sophisticated technical tools, some of which are automated and deployed on a large scale for maximum impact (OECD, 2015j).

Political globalisation

While the State is poised to remain the dominant actor in national and international affairs in the near future, increasing international connectivity between a range of actors, including multinational enterprises, global civil society movements and cities, means the environment for tackling global problems is changing. At the same time, the extraordinary economic development of Asia in recent decades implies a historic shift in economic and geopolitical power that calls into question the legitimacy of many existing post-Second World War multilateral institutions. Lack of representation remains a major concern, particularly among international financial institutions, which has driven some emerging economies to establish parallel national and multilateral mechanisms (e.g. development banks, regional trade blocks, and groupings like BRICS). Taken together, this fragmentation of power could make it more difficult for States to forge international consensus on global and regional issues (OECD, 2015k). On the other hand, a number of recent successes on the global governance front deserve highlighting, particularly the Paris COP21 agreement and the UN's Sustainable Development Goals, both of which have strong STI dimensions.

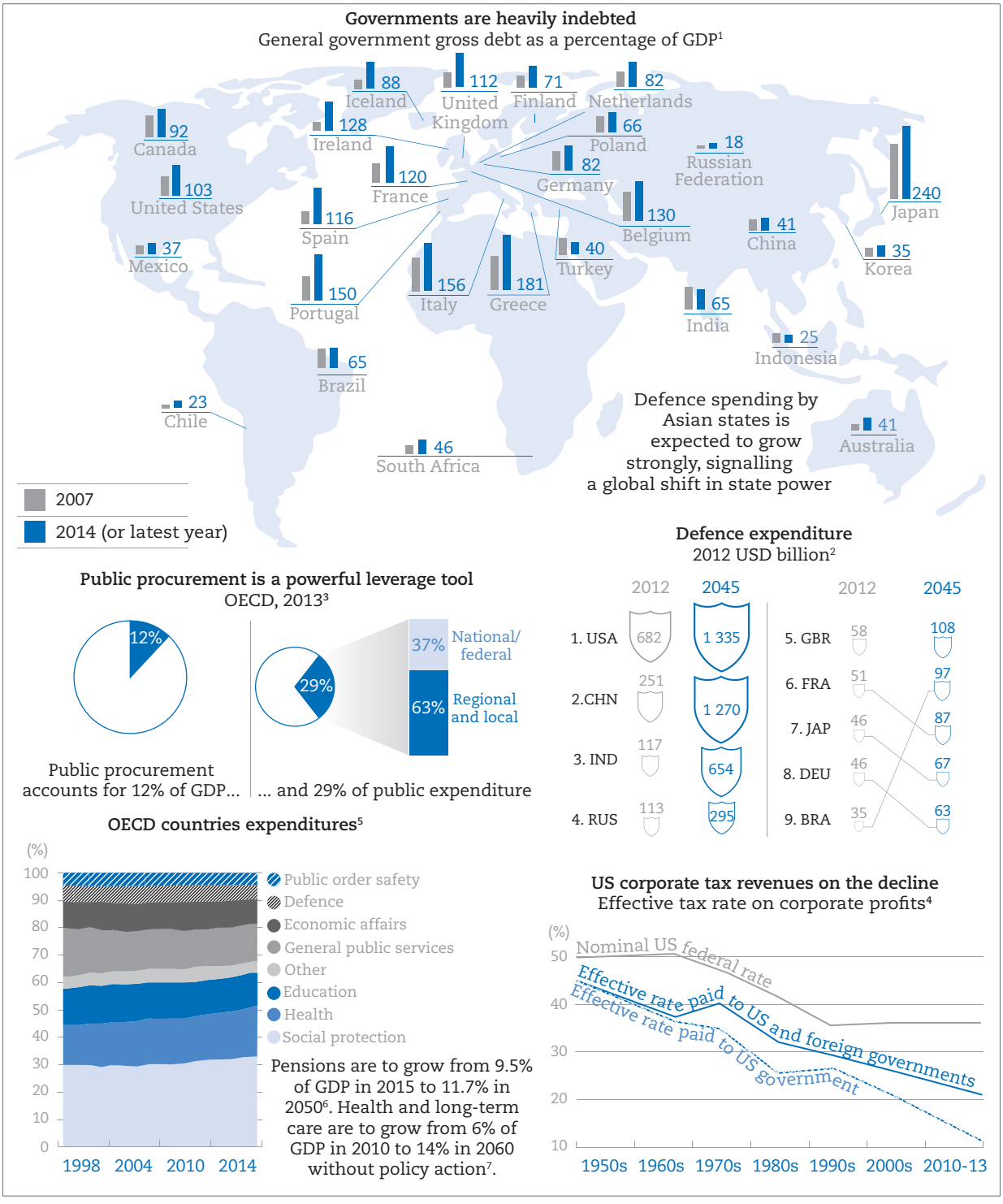
National STI policy is increasingly framed in global terms, reflecting the global nature of many problems and issues, and the globalisation of markets and production. Cross-border governance is therefore of growing importance for STI, particularly in helping address global "grand challenges" such as climate change and threats to health and resource sufficiency. However, international frameworks in many STI areas are still in their infancy and are affected by several barriers, particularly difficulties in trying to co-ordinate

collective funding via national funding regimes. Countries also have concerns about the appropriation of the benefits of pooling public investments in research and innovation, given the emergence of STI as a focus of national industrial policy (OECD, 2015i).

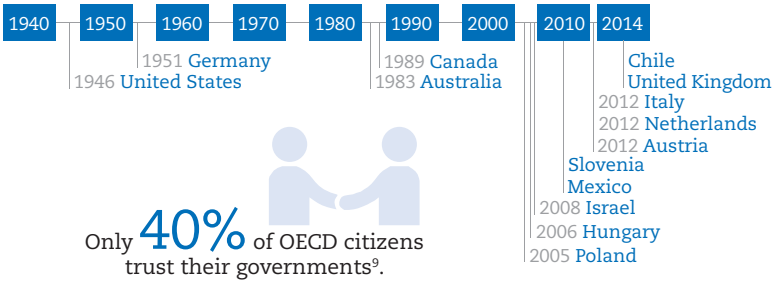
International mobility through tertiary education

International mobility among highly educated individuals at different stages of their personal development and professional careers is a significant driver of knowledge circulation worldwide. A key stage is tertiary-level education, where students that study or spend some time in a foreign tertiary-level institution will build links with other individuals and acquire competences that can be carried over to other places during their working lives (OECD, 2015g). There has been more than a fivefold increase in foreign students since the mid-1970s. The number stood at around 0.8 million worldwide in 1975 and had risen to more than 4 million by 2010. Foreign students are highly concentrated in a few countries, as almost half go to the top five destination countries (the United States, the United Kingdom, Germany, France and Australia). Nevertheless, the fastest growing destination regions are Latin America and the Caribbean, Oceania and Asia, reflecting university internationalisation in a growing set of countries (OECD, 2012b). Looking ahead, the number of students seeking study abroad could double to 8 million by 2025. Average annual growth in demand for international higher education between 2005 and 2025 is expected to exceed 3% in Africa, the Middle East, Asia, Central America and South America (Goddard, 2012). The top sending countries for international students in 2025 are expected to be China, India, Germany, South Korea, Saudi Arabia, Nigeria, Turkey, Pakistan, France and Kazakhstan, and students from China and India are predicted to make up roughly one-third of the total number (British Council, 2013).

Role of governments



OECD countries are increasingly opting to regulate lobbying[8]

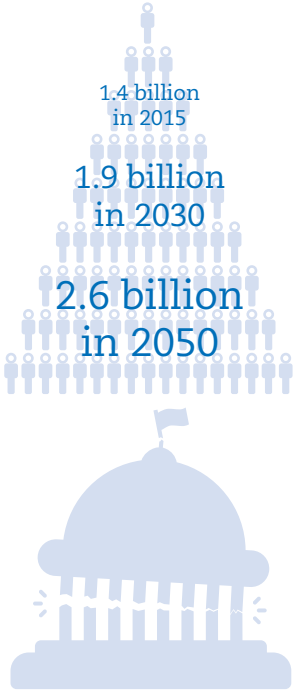


Only **40%** of OECD citizens trust their governments[9].

Largest corporates to rival governments?
USD billion[10]

Country/company	GDP/profits
Luxembourg	58
Apple	54
Uruguay	53
Costa Rica	51
Croatia	49
Tanzania	45
ICBC	44
Slovenia	43
China Construction Bank	36
Agricultural Bank of China	29
Latvia	27
Bank of China	27
Berkshire Hathaway	24
JPMorgan Chase	24
Estonia	23
Wells Fargo	23
Surgutneftega	20
Toyota Motor	19
Cambodia	18
Gilead Sciences	18
Verizon Communications	18
Novartis	18
Iceland	17
China Mobile	17
Alphabet	17
Samsung Electronics	17

More people will live in fragile states[11]



Rise of megacities: a challenge to nation states?[12]

Megacities may become the epicenter of social, economic and political development, displacing national states in some instances.

Relations with science and innovation

- Governments will continue to play an essential role in guaranteeing scientific autonomy and supporting fundamental science.
- Governments will likely become increasingly proactive in promoting green innovation, using funding for R&D, tax incentives, innovative procurement, standards and regulation.
- The shift to a more multipolar world may increase security uncertainties and possibly spark new arms races, which would likely influence government spending on STI.
- Governments will continue to collect and increasingly make open large amounts of data that are useful for research and innovation.

Government capacity

- While governments will remain the largest investors in public R&D, mounting debt burdens, dwindling tax revenues and rising expenditures on pensions and healthcare could compromise their capacity to fund STI activities at current levels.
- Technological change will present governments with new challenges to manage innovation rents, e.g. through competition policy, and workforce re-skilling, e.g. through education.
- Governments are themselves innovating, conducting experiments and relying increasingly on digital technologies for policy formulation, delivery and evaluation.

Non-state actors

- Cities and regions will become increasingly significant public funders of research and innovation.
- Governments will increasingly partner with businesses, NGOs and philanthropists to support STI, which will influence public research agendas.

Sources: 1. "General government gross debt", in OECD (2015l); 2. ESPAS (2015); 3. OECD (2015l). "Other" includes environment protection, housing etc.).; 4. Zucman, G. (2015); 5. OECD (2016e); 6. "Projections of public pension expenditure as a share of GDP from 2015 to 2050", in OECD (2014g); 7. de la Maisonneuve and Martins (2015); 8. OECD (2014h); 9. OECD (2015l); 10. Forbes (2016); World Bank national accounts data; OECD National Accounts; 11. OECD (2015m); 12. UNDESA (2015b).

The changing economic development roles of government

Historically, many OECD countries implemented highly interventionist industrial policies, often owning the means of production in certain key industries or favouring a few private sector "national champions". These sorts of policies mostly fell out of favour from the 1970s onwards and were replaced by policies that are more horizontal in nature with a focus on improving the framework conditions for all businesses. Such conditions involve enforcement of competition rules, trade openness, the availability of skills (education and vocational training), etc. However, following the recent economic crisis, many OECD countries have shown renewed interest in a more targeted industrial policy. Concerns about a loss of manufacturing capacities, and growing competition from emerging economies, have also contributed to a surge in interest, as has the prospect of a science and technology-driven "new production revolution".

This new approach differs from previous generations of industrial policy. It involves facilitating and co-ordinating roles for government and new ways for government and industry to work together, while also avoiding undue influence from vested interests (Warwick, 2013). Linkages are important for innovation, but do not always operate efficiently, motivating governments to support, among other things, research co-operation, as well as knowledge sharing between firms or between firms and universities. Support to technological development is also "upstream" from the previous "picking winners" focus, with governments supporting general purpose technologies so as not to impede downstream competition or infringe State aid rules in international treaties. Support is also increasingly challenge-focused, as governments seek to redirect technological change from path-dependent trajectories towards more socially and environmentally beneficial technologies and to spur private STI investments along these lines.

Technological change, particularly digitalisation, presents governments with new challenges to manage innovation rents. Policy makers will need to deploy a range of policies that, on the one hand, enable the most innovative firms to invest in frontier innovation and access skilled workers, finance, and markets, while on the other, support the diffusion of innovation throughout the rest of the economy, thus enabling all firms to benefit from these innovations (OECD, 2016f).

Finally, the workings of government have come under the innovation spotlight. For example, given governments collect large amounts of data and increasingly make this openly available, major research and innovation opportunities exist to exploit this using big data analytics. Governments are also increasingly innovating themselves, conducting experiments and relying increasingly on digital technologies for policy formulation, delivery and evaluation.

The role of government in supporting research

State-sponsored public research plays a key role in innovation systems and decision-making processes. It is a source of new knowledge, especially in areas of public interest, such as basic science or fields related to social and environmental challenges, which businesses are not always well equipped or motivated to invest in. Furthermore, governments play a fundamental role in guaranteeing scientific autonomy. They also support 10%-20% of business R&D expenditure in most OECD countries. The standard market failure rationale for

this public support is that firms tend to underinvest in R&D on account of its costs and uncertainty, the time required to obtain returns on investment, and the possibility that competitors can capture knowledge spillovers (owing to the non-rival and partly-excludable nature of R&D). All of these rationales for supporting public research and firms' R&D will likely remain sound over the next 10-15 years. The question is whether governments will be able to afford the investments required.

A fiscal crisis of the State?

Fiscal pressures are likely to continue to build up in many countries as demographics evolve unfavourably, and spending pressures stemming from pensions, health, education and infrastructure investment intensify. On average across the OECD, public social expenditure rose from just over 15% of GDP to almost 22% of GDP between 1980 and 2014. Governments are also increasingly indebted, particularly since the financial crisis, and many have recently adopted austerity measures to reduce or even reverse high debt/GDP ratios. At the same time, globalisation has opened up opportunities for multinational enterprises (MNEs) to greatly reduce the taxes they pay. The use of legal arrangements that make profits disappear for tax purposes or allow profits to be artificially shifted to low or no-tax locations result in annual tax revenue losses conservatively estimated at between USD 100 billion and USD 240 billion. This is equivalent to between 4% and 10% of global revenues from corporate income tax (OECD, 2015n). Despite these pressures, governments will remain the largest investors in public R&D, though their capacity to fund STI activities at current levels could be compromised. In this regard, the latest data on general expenditures on R&D in the OECD area show a slight fall in government funding (see Chapter 3), which could be a "weak signal" of future public spending trends.

A crisis of confidence in government?

In the aftermath of the global economic crisis, public trust in governments and institutions has eroded. There is a sense that governments have failed to respond sufficiently during the unfolding of the crisis or to adequately address its aftermath. Technological change has brought about a productive revolution, but also affected employment and generated new risks associated with privacy and cybercrime. Corruption, whether perceived or actual, high unemployment, rising income inequality and concerns that education systems are out of date and fail to provide equal opportunities, all feed a general belief that governments are unable to protect the best interests of their citizens (OECD, 2015k). This crisis of confidence has implications for STI policy, too, as much R&D continues to be performed in the public sector. Furthermore, governments are expected to perform important normative and regulatory roles in governing research and innovation, such as certifying the safety of new products, roles that are difficult to fulfil in a world of uncertainty brought about by rapid and globalised technological change.

Growing instability in the international State system?

A range of trends and developments occurring at global level and covered elsewhere in this chapter – e.g. the growing importance of emerging and developing countries; the shift in centre of economic gravity towards Asia and the concomitant decline in the relative economic weight of North America and Europe; and the rise of GVCs – convey a shift to a

more multipolar world. This shift is already generating growing uncertainties in the international system.

Looking back, the last two decades have witnessed a gradual decline in the number (and severity) of internal armed conflicts worldwide – from a peak in 1994 when almost a quarter of the world's countries were embroiled in civil conflict, to less than 15% today. This has been much the result of widespread improvements in factors such as levels of education, economic diversification and more favourable demographic developments (Hegre and Nygard, 2014). The number of interstate conflicts, while fluctuating somewhat, has also been on a declining trajectory (Petterson and Wallensteen, 2015), thanks mainly to a rising body of global norms against such warfare and the deepening economic and financial linkages among countries. Unsurprisingly, when it comes to forecasting the longer-term outlook for armed conflict, views diverge. Hegre and Nygard (2014), for example, forecast that this downward trend will continue, with the share of countries involved in internal armed struggles falling from 15% now to 12% in 2030, and 10% in 2050, and with conflicts concentrated mainly in sub-Saharan Africa and South Asia. Others are somewhat less sanguine. The US National Intelligence Council (NIC, 2012) states that the risks of interstate conflict are on the rise owing to changes in the international system, but does not foresee conflict on the level of a world war involving all major powers. This heightened risk could see governments increase their defence spending. In many countries, a large share of public support for R&D is already provided to firms in the defence industry to develop military equipment and potentially civil applications. Any rise in international tension could see this share increase further.

Today, 50 countries are fragile states, marked by either weak or abusive state institutions (OECD, 2015m). They are home to 1.4 billion people, though their population is projected to grow to 1.9 billion in 2030 and 2.6 billion in 2050. Sub-Saharan Africa is by far the most represented region. The weak capacity of fragile states to respond to shocks and stresses means they face heightened risk of experiencing future political, social or humanitarian crisis (OECD, 2015m). Such crises can easily spill over into neighbouring countries and even further afield, with consequences for health, migration, etc. Global responses to some of these crises, particularly those concerning global health threats, are likely to have a major influence on future STI agendas.

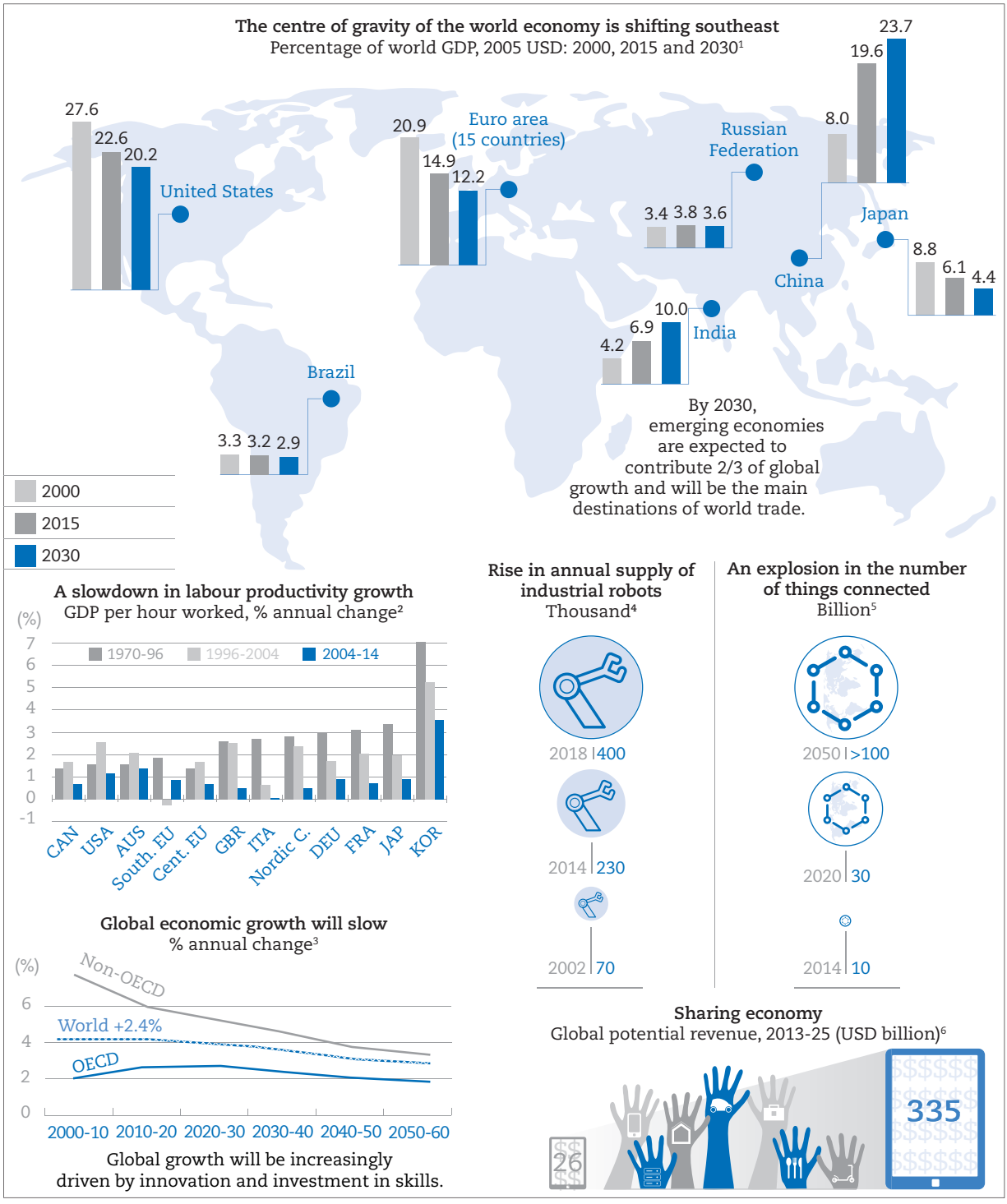
Growing significance of non-state actors

Non-state actors such as multinational businesses, non-governmental organisations, sovereign wealth funds, megacities, academic institutions and foundations endowed with global reach are all expected to play increasingly influential roles in the coming decades. In some cases they may even prove instrumental in the creation of new alliances and coalitions that have wide public support to tackle some of the global challenges facing the planet – poverty, environment, security, etc. (NIC, 2012). In the STI realm, businesses are the main funders of R&D and the locus of most innovation activities. Governments will increasingly partner with businesses, NGOs and philanthropists to support STI, which will influence public research agendas (see Chapter 3).

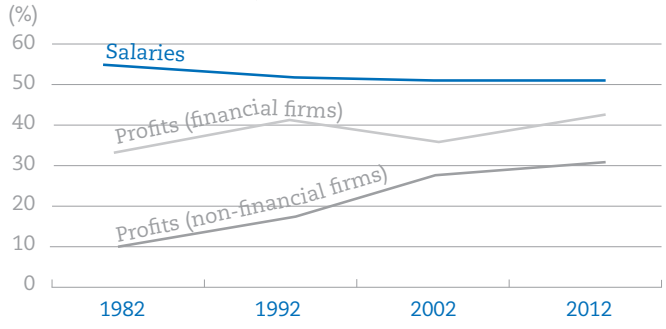
Cities, and in particular megacities, stand out as one of the increasingly powerful subnational actors. Metropolitan areas are the prime engine of growth. In the OECD area, more than half of economic growth and job creation occurred in the 275 metropolitan areas

with over 500 000 inhabitants (OECD, 2013c). The number of megacities of 10 million or more inhabitants has almost tripled over the last 25 years, and they now account for 12% of the world's urban population. Forty or so such cities will exist by 2030. Cities and regions are already supporting research and innovation activities in their jurisdiction and an increasing number have formulated innovation strategies, a trend that is likely to continue.

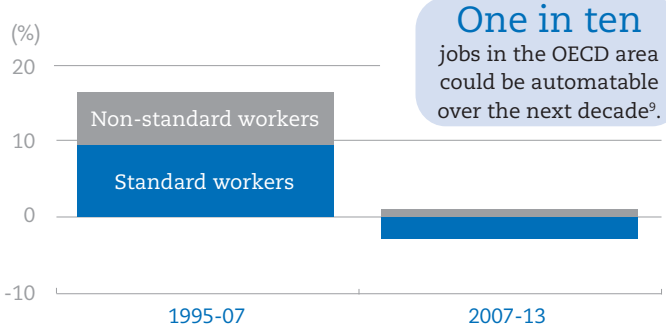
Economy, jobs and productivity



What about wages?
% of value added[7]



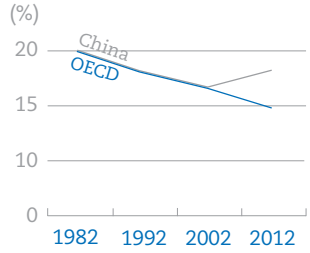
Growing precarity of employment
% employment growth, 2007-13, by type of employment[8]



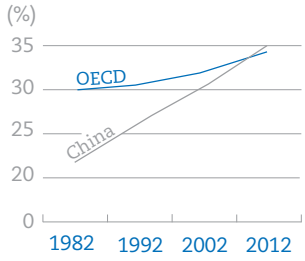
One in ten jobs in the OECD area could be automatable over the next decade[9].

More than half the jobs created since 1995 are non-standard, i.e. part-time, temporary or self-employment arrangements.

Less manufacturing jobs
% total employment[10]



More jobs in R&D-intensive industries
% of manufacturing employment[10]



The persistent decline in manufacturing employment has affected some sectors more than others, with relatively fewer jobs shed in R&D-intensive industries.

Future productivity

- Given population ageing, future income growth will be increasingly driven by innovation and investment in skills.
- Yet, declines in knowledge-based capital accumulation, together with "winner-take-all" business dynamics, could slow the arrival of breakthrough innovations and their diffusion across economies.
- Asian economies are expected to climb up the global value-added ladder. These changes will be accompanied and, in part, driven by big investments in STI.

Digital technologies

- The growing maturity and convergence of digital technologies are likely to have far-reaching impacts on productivity and income distribution.
- A digital platform economy is fast emerging, creating greater opportunity for entrants – including individuals, outsider firms and entrepreneurs – to succeed in new markets.
- Digital technologies will further disrupt all sectors. For example, in financial services, Fintech promises to disrupt the sector through digitally-enabled P2P lending platforms, equity crowdfunding, online payment systems, cryptocurrencies and blockchain.

Future jobs

- Advances in machine learning and artificial intelligence are expected to expand the capabilities of task automation and could lead to a further hollowing out of employment and wages. They will also likely create new jobs that, as yet, have not even been imagined.
- Digital platforms that mediate work could lead to more "non-standard" jobs and contribute to the rise of the so-called "gig economy".

Sources: 1. OECD (2014i); 2. OECD (2016f); 3. OECD (2014j); 4. International Federation of Robotics (2015); 5. Gartner (2013); 6. OECD (2016g); 7. OECD (2016h); 8. Arntz, Gregory and Zierahn (2016); 9. OECD (2015r); 10. OECD (2015g). The loss of manufacturing jobs in the OECD area has affected some industries more than others. Over the past 30 years or so, a steadily increasing share of OECD manufacturing employment has come from R&D-intensive industries, rising from 30% to about 35%. In other words, relatively fewer jobs have been shed in this group of industries (chemicals, machinery and transport equipment) compared to others (e.g. textiles, plastics and basic metals). Changes in global production patterns have seen manufacturing in China become more orientated around R&D-intensive industries, with the share of employment rising from 20% in the early 1980s to about 35% in recent years. However, a high presence of R&D-intensive industries does not necessarily indicate high levels of R&D expenditure, as much R&D can be embodied in imported intermediate goods.

The future of productivity growth

Global growth is estimated to slow from 3.6% in 2010-20 to 2.4% in 2050-60. Given population ageing, income growth will be increasingly driven by innovation and investment in skills (Braconier et al., 2014; Adalet McGowan et al., 2015). However, labour productivity growth has slowed in many OECD countries over the last two decades, which mainly reflects slowing total-factor productivity growth. A pessimistic view holds that this is a permanent phenomenon, on account of a decline in the underlying rate of technological progress. According to this perspective, the types of innovations that took place in the first half of the 20th century (e.g. electrification) are far more significant than anything that has taken place since then (e.g. ICT), or indeed, is likely to transpire in the future (Gordon, 2012; Cowen, 2011). Technological optimists (e.g. Brynjolfsson and McAfee, 2011), on the other hand, argue that the underlying rate of technological progress has not slowed and that the IT revolution will continue to dramatically transform frontier economies (OECD, 2016i).

Recent OECD analysis of productivity trends suggests that the main source of the productivity slowdown is not the slowing of the rate of innovation by the most globally advanced firms, but rather a slowing of the pace at which innovations spread throughout the economy: a breakdown of the so-called "diffusion machine" (Andrews, Criscuolo and Gal, 2015). There are several possible explanations for this concentration: for example, it could be that we are at the start of a new technological trajectory, with developments dominated by a few early adopters. Given technological dissemination follows a sigmoid curve, there is a lag before it diffuses more widely. But another explanation that is attracting increasing attention is "winner-take-all" dynamics, which appear to be particularly prevalent in some industries, such as those involving digital platforms (see below). Since the financial crisis, persistently weak investment in physical capital (machines and equipment, physical infrastructure) has also contributed to a slowdown in labour productivity growth. But perhaps more worryingly, there has also been a slowdown since the early 2000s in knowledge-based capital accumulation, which usually underpins innovations and their subsequent adoption. This decline raises concerns about a structural slowdown in productivity growth and may foreshadow a possible slowdown in the arrival of breakthrough innovations (OECD, 2016i).

Long-term investment plays a key role in promoting innovation-based growth and job creation. Most company investment is carried out with retained earnings, with relatively small recourse to external finance. In recent years, companies have allocated a significant proportion of retained earnings, backed by low-interest rate borrowing, to shareholders in the form of dividends and buybacks. These cash returns have reduced companies' long-term "growth" investments. OECD estimates that companies in advanced economies could increase capital expenditure on average by 60% without any recourse to borrowing, simply by reducing dividends and buybacks (OECD, 2016i). A key policy challenge will therefore be to establish long-term investment incentives that offset tendencies in the financial system to measure profit margins on a short-term basis (WEF, 2011).

The centre of gravity of the world economy is moving east and southwards

The next 50 years will see the centre of gravity of the world economy shift east and south. By 2030, developing countries are expected to contribute two-thirds of global growth and half of global output, and will be the main destinations of world trade. Emerging economies such as China and India are increasingly important markets for firms in many industries. A new middle class is fast emerging that will lead to a rise in consumption of basic consumer products and other product categories. These demand-side factors mean

emerging economies are likely to remain favoured locations for production activities, reducing the likelihood of widespread re-shoring to OECD countries (OECD, 2015h). Furthermore, income gains and changing consumption patterns mean that manufacturing exports from China, India and other Asian economies are expected to climb up the global value-added ladder, while significant shifts towards services will see China and other emerging economies gain large shares in services trade at the expense of OECD countries in the long-run (Johansson and Olaberria, 2014b). These changes will be accompanied, and, in part, driven by investments in STI. For example, research spending in China is already second only to the United States (see Chapter 3).

Digital technologies will further disrupt economies

The growing maturity and convergence of digital technologies are likely to have far-reaching impacts on productivity, income distribution, well-being and the environment. By 2030, firms will be predominantly digitalised, enabling product design, manufacturing and delivery processes to be highly integrated and efficient. Additive manufacturing technologies will allow certain products to be tailored to specific user needs, while the IoT, big data analytics, artificial intelligence and machine learning tools will enable smart machines to emerge that will be increasingly adjustable through sensor technologies, cheap computing power and the real-time use of algorithms (OECD, 2015h).

The costs of equipment and computing will continue to fall, while the rise of open source development practices will create further communities of developers, not only in software but also in hardware and "wetware", e.g. in "do-it-yourself" synthetic biology (see Chapter 2). There will be greater opportunity for entrants – including individuals, outsider firms and entrepreneurs – to succeed in new markets. Pattern-recognition technologies, such as big data and machine learning, will enhance capabilities for assessing user needs and overall demand for innovation. The risks and time-spans in product development and market launch are expected to decrease, spurring additional developments. Innovation-related production costs will fall in key industries, with cloud computing and 3D printing services providing platforms for new firms. Product distribution costs will continue to fall, reducing the cost of launching new products and services (OECD, 2015o). These developments could also provide emerging economies with opportunities to accelerate technological catch-up, possibly allowing them to leapfrog to productivity levels closer to those observed in OECD countries.

In the services sector, digital technologies have helped create new and more efficient businesses, boosted productivity growth, and facilitated international trade in services. Manufacturing in OECD countries increasingly thrives on services inputs for value creation, and the differences between manufacturing and services have become increasingly blurred. A large part of future growth in production is expected to come from so-called "manu-services", which involve combining advanced manufacturing with a range of different services. The growing and complex interactions between manufacturing and services will call for a more integrated view on manufacturing and services in company strategies, as well as in policy discussions (OECD, 2015h).

The rise of digital platforms

A digital platform economy is fast emerging. By 2015, operators of digital platforms almost fully dominated the top 15 of the world's largest Internet-based companies ranked by market capitalisation (OECD, 2016j). Platforms are diverse in range and function. For

instance, they provide platforms on which applications are built (e.g. Google's Android and Apple's iOS); they support search and social media (e.g. Google and Facebook); they provide services (e.g. Airbnb and Uber); they offer marketplaces (e.g. Amazon and eBay); and they mediate work (e.g. Amazon's Mechanical Turk and UpWork). Platforms lower barriers for small providers to enter markets. Together, they are reorganising a wide variety of markets, work arrangements, and ultimately value creation and capture (Kenney and Zysman, 2016). This implies potentially radical economic and social disruption that will create winners and losers.

Once a platform's networks have reached critical size, network externalities can protect the platform's position and function as barriers to entry for other firms or platforms (OECD, 2016i). These network effects imply that innovations associated with digital platforms are a new version of natural monopolies where one or two firms become dominant and are able to appropriate a generous portion of the entire value created by all the users on the platform (OECD, 2016i; Kenney and Zysman, 2016).

Future jobs

The decreasing cost of computing power and other advances in digital technologies are already disrupting labour markets and making some workers redundant (see Brynjolfsson and McAfee, 2011). Computers have begun displacing labour when it comes to explicit (codifiable) routine tasks that follow precise and well-understood procedures such as clerical work (e.g. accounting) and some physical operations in production lines. For the time being, tasks that are hard to describe as a set of steps and are bounded to particular circumstances remain impervious to automation (Autor, 2015). These tasks are more abstract in nature and often involve problem-solving capabilities, intuition, creativity and persuasion. However, advances in machine learning and artificial intelligence are expected to expand the capabilities of task automation and could lead to more dramatic changes than experienced in the past, and in particular, to a further hollowing out of employment and wages. Recent research conducted for the OECD (Arntz et al., 2016) suggests that around one in ten jobs across the OECD are at high risk of automation. At the same time, these innovations harbour great promise for more robust productivity growth and new jobs that, as yet, have not even been imagined (OECD, 2016i).

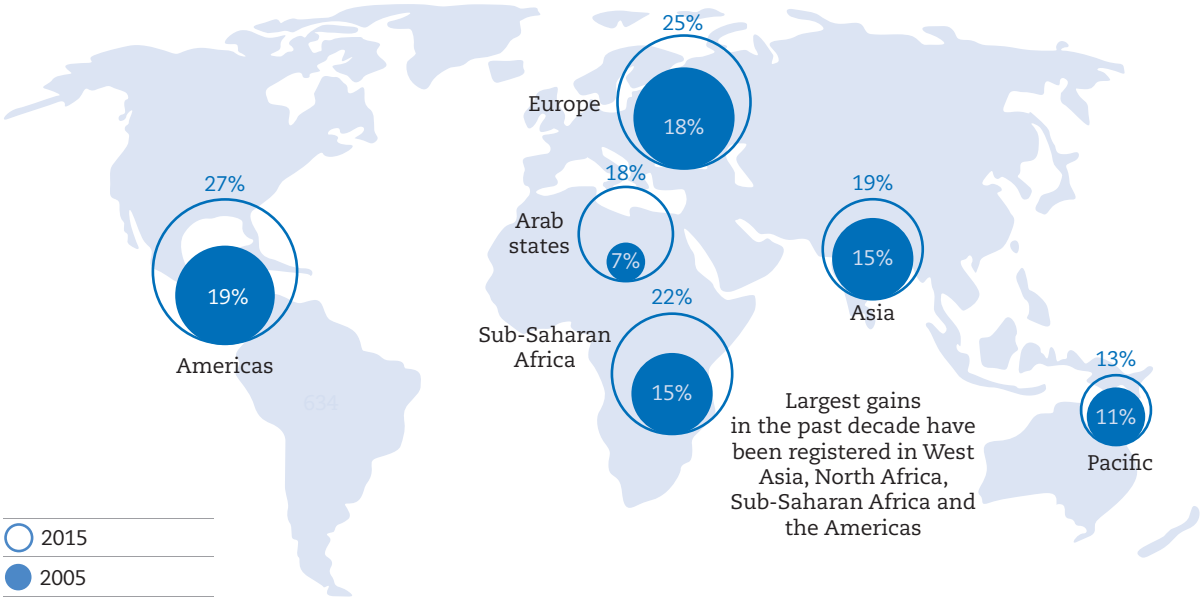
Depending on how quickly economies are able to create new jobs to replace those that have been lost and how wages will evolve, there may still be too few jobs, perhaps on a permanent basis. Greater work-sharing and a reduced working week could help distribute work more evenly, but would need to guarantee a living wage – possibly through some sort of "universal basic income" (Skidelsky, 2013). Work has already become more fragmented and "non-standard", with an increasing number of workers doing lots of different part-time jobs – the rise of the so-called "gig economy". The growth of online platforms that link a vast pool of freelancers, who are physically based in different parts of the world, with companies inviting them to bid to work on a wide variety of tasks, could accelerate this trend. While such platforms offer flexibility to workers and companies, they raise some difficult questions about workplace protections and what a good job will look like in the future (OECD, 2016k). Furthermore, two of the biggest markets for these platforms are India and the Philippines, where lower costs of living allow workers there to undercut their peers in OECD countries. This could trigger a "race to the bottom", driving down real wages and increasing inequality in OECD countries (Fox and O'Connor, 2015).

The future of finance

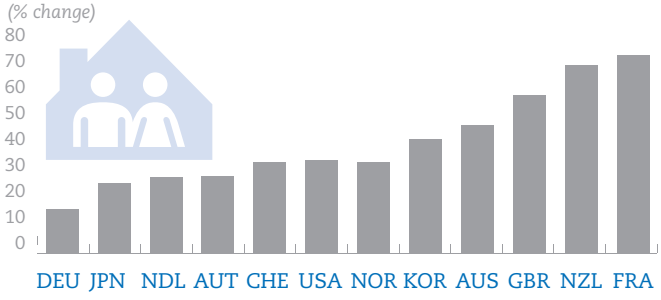
OECD countries have experienced an upwards trend in the value-added share of the financial sector in GDP over the past half-century, which has coincided with the sector's growing influence on the overall economy and society (Mukunda, 2014). The sector's rising profit share is considerably higher compared with the rest of the economy and its high wages have attracted some of the best talent, possibly at the expense of sectors with greater potential for productive innovation (Cournède et al., 2015; Cecchetti and Kharroubi, 2015). While these trends may hold over the next 10-15 years, if not intensify as financial services further develop in emerging economies, "fintech" promises to disrupt the sector considerably. For instance, banks' lending role will be increasingly challenged by digitally-enabled peer-to-peer lending platforms, while equity crowdfunding is also expected to grow (OECD, 2015p). Online payment systems (such as PayPal) and cryptocurrencies (such as Bitcoin) are also forecast to proliferate. Other innovations leveraging the blockchain will lower transaction costs and provide computationally inexpensive methods for securely transferring value. This could disrupt those institutions, like banks, whose raison-d'être lies in the centralised provision of trust behind transactions.

Society

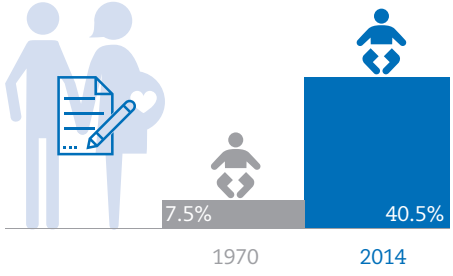
Despite some progress, the gender gap is still prominent
Average proportion of women in parliaments in different regions[1]



Households are getting smaller
Projected increase in the number of one-person households (early-mid-2000s to 2025-30)[2]



More births outside marriage
% of all births, OECD-27 average[2]



Communication habits by generation[3]

	Silent generation	Baby boomers	Generation X	Millennials	Generation Z
	(<1945)	(1945-60)	(1961-80)	(1981-95)	(>1995)
Aspirations	Purchase of a principal residence	Job security	Work-life balance	Freedom and flexibility	Security and stability
Symbolic product		TV			3D printers, nano-computing...
Attitude towards technology	Disengaged	Early adopters, PCs on the horizon	Computer literate	Digital natives	Dependent on digital technology
Communication channel	Face-to-face	Face-to-face, telephone, email	SMS, email	Social networks, instant messaging	Video calls on devices

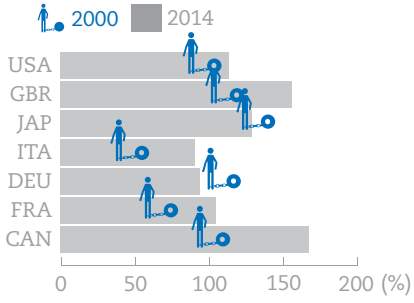
More urbanised

% of the world population living in urban areas[4]

Nearly 90% of urban expansion will take place in Asia and Africa.

More indebted

Household debt-to-income ratios, G7[5]

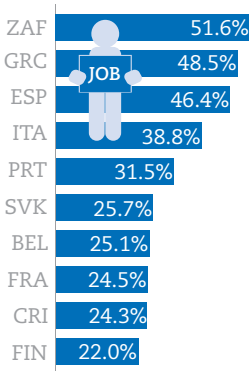


More educated[6]

The number of students enrolled in higher education **will double** globally by 2025 to 260 million.

More fragile

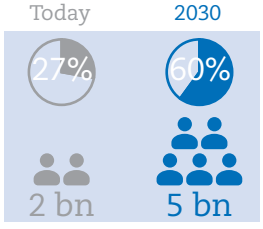
Youth unemployment rate[7]



+16% in OECD youth unemployment since 2008.

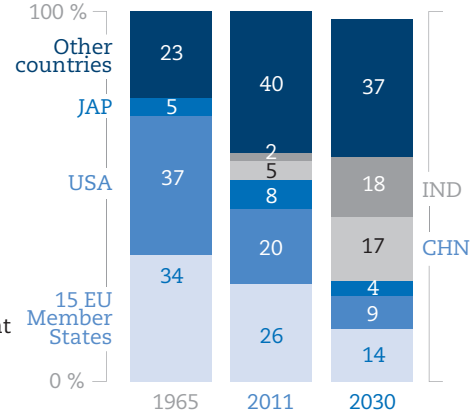
A growing middle class[8]

Size of middle class



By 2030, it will **more than double**. Asia will host **64%** and account for over **40%** of global middle-class consumption.

Middle-class consumption breakdown



Social agendas and STI policy

- Societal challenges, e.g. food security, clean energy, climate action, etc., are increasingly influencing STI policy agendas. This in turn could lead governments to use broader notions of research impacts in their research assessments.

Science and innovation in society

- Digital technologies are transforming societies, altering the ways in which people live, work and communicate. Ubiquitous connectivity will support more flexible working arrangements, though with uncertain consequences for work-life balance.
- New technologies – such as ICTs, synthetic biology, additive manufacturing, nano- and micro-satellites, and advanced energy storage – will empower individuals and social collectives (e.g. NGOs) to conduct their own research and innovation activities.
- A more highly-educated citizenship could become increasingly interested and engaged in the debates around the direction of STI developments, particularly with regards to associated benefits, risks and values.

Urbanisation and consumption

- A growing middle class and increasing consumption in emerging economies will increase demand for innovative consumer goods worldwide.
- In OECD countries and some emerging economies, urban areas will become increasingly "smart", influencing the direction of innovation in sectors such as housing and transportation.
- By contrast, urban development in many developing countries will present health challenges, including the increasing risk of global pandemics. These challenges could have a significant influence on future research agendas.

Sources: 1. IPU (2016); 2. OECD (2016l). The periods over which changes are projected (early-mid-2000s to 2025-30) are as follows: Australia (2006-26), Austria (2007-30), France (2005-30), Germany (2007-25), Japan (2005-30), Korea (2007-30), Netherlands (2009-30), New Zealand (2006-31), Norway (2002-30), Switzerland (2005-30), United Kingdom (2006-31) and United States (2000-25).; 3. Le club des élus numériques (2014); 4. OECD (2012a); 5. OECD and PBO (2016). OECD data for Japan is available only to 2013. The values shown for Japan correspond to 2000 and 2013.; 6. Goddard (2012); 7. OECD (2016h); 8. EEA (2016a). The 15 chosen EU countries are: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. No Chinese data for 1965.

Families and households

In recent decades families in the OECD area have undergone significant transformation. The extended family has almost disappeared in many countries, and the traditional family consisting of a married couple with children has become much less widespread as divorce rates, cohabitation, couples "living apart together", single parenthood and same-sex partnerships have all increased. With rising migration, cultures and values have become more diverse, more women have taken up work, more young people are spending more time in education and training, and the elderly are living longer and increasingly alone (OECD, 2011). The expectation is that these trends will continue over the coming decades, with significant increases in many OECD countries in: one-person households (reaching 30-40% of all households by 2025-30 in many countries), single-parent households (30-40% of all households with children by 2025-30 in some countries), and couples without children. The increase in childless couple households, divorce rates, remarriages and step-families may weaken family ties and undermine capacity for informal family care, while the growing numbers of single-adult households will put increased pressure on housing (OECD, 2011). From an STI perspective, these household trends will have impacts on consumption and demands for innovation, while the likely gap in elderly care provision will increase demand for assisted living technologies, including telecare and robotics.

Closing gender gaps

There are various signals that the gender gap is closing, given women's growing involvement in politics, rising enrolment rates in higher education and increased participation in the labour market. At the higher education level, gender equality is making significant inroads. In most OECD countries, women already account for at least 50% of tertiary education enrolments. The emergence of such strongly qualified female cohorts has important implications for economic growth, labour markets, family life, patterns of childcare and elderly care. In the developing world, girls' enrolment at all levels of schooling has risen significantly over the last two decades. There is a good deal of optimism that by mid-century, global gender gaps at the primary school level will have largely disappeared, although girls are likely to remain under-educated in many of the world's most intractably poor countries (UK Ministry of Defence, 2014). In the STI field, while there has also been some progress in addressing gender gaps the proportion of female scientists tends to fall as seniority rises (see Chapter 3); there are more male than female entrepreneurs, and the share of women who choose to run a business has not increased substantially in most countries (OECD, 2015q); and most scientific research does not consider sex or gender as variables and treats male as the norm, resulting in different health and safety outcomes for women and men (EC, 2013). These outstanding gaps underutilise women's skills and limit the benefits of today's science.

More connected societies

Digital technologies are transforming societies, altering the ways in which people live, work and communicate. Over the coming decade, the IoT, for example, will see homes, workplaces and the wider environment (e.g. advanced city infrastructures) increasingly interconnected. This ubiquitous connectivity will support more flexible working arrangements, though with uncertain consequences for work-life balance. For the developing world, Internet penetration has been growing quickly, helped considerably by mobile broadband. It is estimated that over the seven-year period from 2014 to 2020, an

additional 1.1 billion new individuals will acquire a mobile phone for the first time, or 155 million per year. According to Ericsson (2015), mobile broadband subscriptions will reach 7.7 billion globally by 2020.

Global middle class and consumption

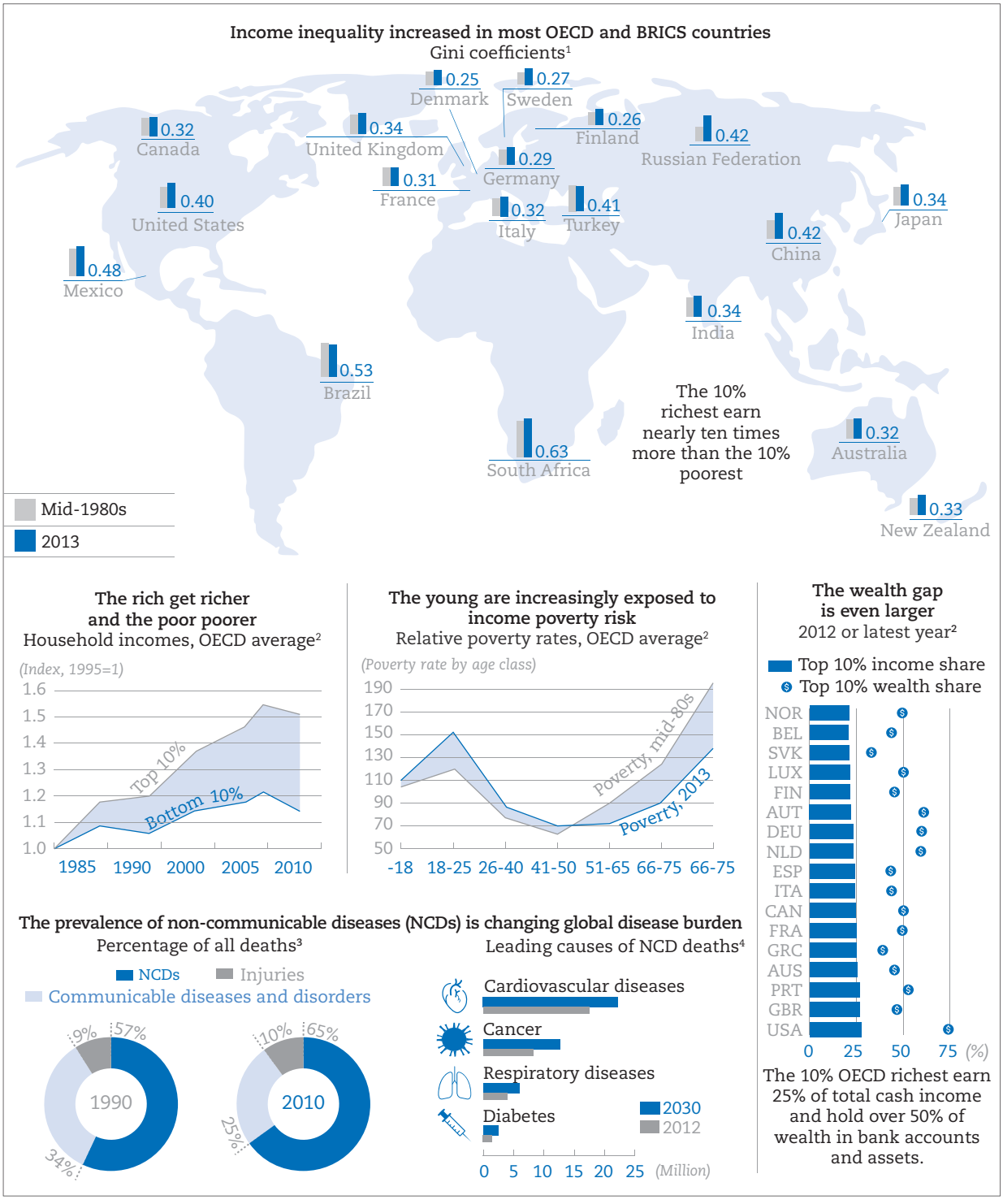
Rising wealth and income in the developing economies of the world is progressing hand in hand with the emergence of a global middle class. By current projections, the global economy's middle class is expected to more than double between 2009 and 2030, from 1.8 billion to almost 5.0 billion, accounting for about 60% of the world population. Some two-thirds of those middle-class citizens are expected to be found in Asia (Gros and Alcidi, 2013). Given the broad range of expenditures that fall within the middle-class definition, some countries have more affluent middle classes than others. Today's middle class in Europe and North America make up just over half of the global total in terms of number of people, but they account for almost two-thirds of total spending by the world's middle class. This is about to change. Asia's share of global middle-class expenditure is expected to climb from around one-quarter today to almost 60% in 2030, bringing about a huge shift from spending on necessities such as food and clothing to choice-based spending on categories such as household appliances and restaurants (Kharas and Gertz, 2010).

Urbanisation

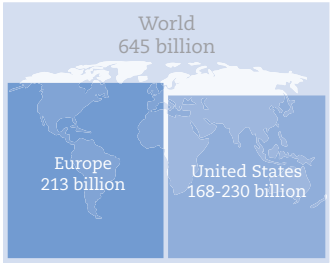
By 2050, the urban population is expected to surpass 6 billion – up from less than 1 billion in 1950 (OECD, 2015s). Almost all urban population growth will occur in cities in developing countries, with nearly 90% occurring in Asia and Africa. Cities make it easier to provide modern energy and water infrastructures to a growing number of people. Building on advances in sensors and their connectivity through high-performance computing, urban areas in more advanced economies will increasingly become "smart cities". Various utility and transport networks and systems will become progressively interconnected, thereby supporting more sustainable use and management of resources (EC, 2014).

At the same time, a growing proportion of low-income groups will become urbanised over the next decades, so that in some regions, urban growth will become virtually synonymous with slum formation. Urban slums suffer from sub-standard housing and inadequate water, sanitation and waste management services, all of which have negative consequences for human health and the environment (OECD, 2012a). Such areas are also more likely prone to conflict and social unrest (UK Ministry of Defence, 2014). Air pollution and unmanaged waste will be major concerns for public health in many urban areas (OECD, 2012a). Climate change will see storm surges and rising sea levels increase over the next decades, which will have major impacts on low-lying coastal cities, especially in Asia, where so much of the world's urban population lives. Extreme weather events will also disrupt complex urban systems (OECD, 2014k), while the proximity of emerging megacities to areas of severe water stress and pollution will likely give rise to new health and environmental problems. Given their seriousness, these challenges are likely to have major impacts on future STI agendas.

Health, inequality and well-being

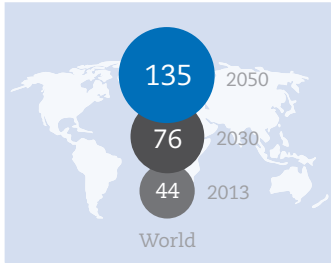


Financial cost of dementia
USD billion, 2013[5]



The global cost of dementia is equivalent to the GDP of Switzerland.

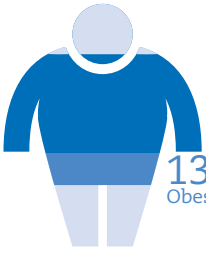
Prevalence of dementia
Million inhabitants[5]



By 2030, dementia cases will rise by +50% in high-income countries and +80% in lower income countries.

Obesity on the rise[6]

Adult obesity, 2014



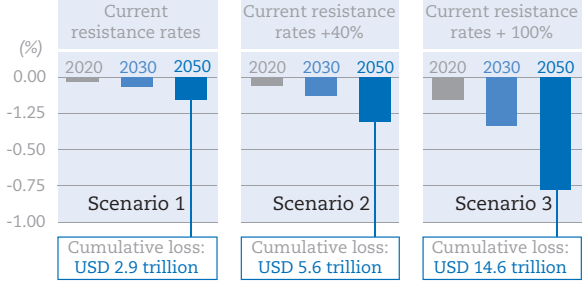
39%
Overweight
13%
Obese

Child obesity, 2014

41 million
children under the age of 5 were overweight or obese in 2014.

Worldwide obesity has more than doubled since 1980.

Economic impact of antimicrobial-resistance
GDP loss in OECD countries per year[7]



Today, 700 000 deaths per annum globally are due to antimicrobial resistant micro-organisms.

Innovation and inequality

- Innovation will increase inequality as benefits predominantly accrue to innovators and possibly their customers. For all actors in society to benefit, innovations must diffuse.
- Furthermore, most new technologies require new sets of skills to use. This possibly contributes to unemployment and inequality, and highlights the need for skills training.
- On the other hand, technologies can directly promote social inclusion and economic growth, e.g. digital technologies have opened up access to education, financial services and other knowledge-based services.
- New concepts such as social innovation, frugal innovation, inclusive innovation and social entrepreneurship are leading to new innovative business models and can contribute to a more inclusive approach to innovation.

Health innovation

- Much of the extension of life expectancy and improvements in quality of life over the last century can be attributed to the success of biomedical research and innovation.
- Pharmaceutical research is entering a new era of open science and the use of converging technologies to uncover the genetic and biochemical underpinnings of diseases.
- Digital technologies will massively increase the amounts of medical data available and enhance the power of data analysis in the service of healthcare decision-making.
- New public and private R&D will be essential to deal with the threat of growing antimicrobial resistance.
- Patient groups are increasingly prominent in shaping research and innovation agendas. Furthermore, "do-it-yourself" science groups and maker communities are likely to be increasingly visible in the healthcare field, enabled by low-cost advanced technologies like synthetic biology and additive manufacturing.

Sources: 1. PovcalNet (2016). Data are based on primary household survey data obtained from government statistical agencies and World Bank country departments. The Gini coefficient is based on the comparison of cumulative proportions of the population against cumulative proportions of income they receive, and it ranges between 0 in the case of perfect equality and 1 in the case of perfect inequality. The poverty rate is the ratio of the number of people (in a given age group) whose income falls below the poverty line; taken as half the median household income of the total population. However, two countries with the same poverty rates may differ in terms of the relative income-level of the poor.; 2. OECD (2015r); OECD (2016m); 3. EEA (2016b). DALY refers to Disability Adjusted Life Years, defined by WHO as "the sum of Years of potential life lost due to premature mortality and the years of productive life lost due to disability".; 4. WTO (2015a); 5. OECD (2015t); 6. WTO (2015b). Data are Europe (2008), Ireland (2010), United Kingdom (2014), United States (2010), and World (2010). There are considerable methodological differences between the studies summarised here, so this figure should be treated as illustrative only. In general, estimates include indirect costs, such as the opportunity cost of informal care, but methodologies for estimating these costs vary. All costs are in US dollars, inflated to 2013 in line with consumer prices, and so may not match the numerical values stated in the source papers.; 7. Cecchini, Langer and Slawomirski (2015).

Wealth and income distribution: towards global convergence

Barring major global catastrophes, and despite slowing global growth rates, the world is very likely to be a much richer place by mid-century. World GDP is expected to more than triple by 2060, per capita incomes are also set to rise rapidly, and wealth accumulation is anticipated to continue apace. However, whether this will also be a better world depends very much on how incomes and wealth will be distributed across the globe and within countries. At present, the prosperity gulf between developed and developing economies remains wide, though has been narrowing for several decades. By 2060, disparities in GDP per capita are expected to further narrow across countries; per capita income levels of the currently poorest economies will more than quadruple (in 2005 purchasing power parity terms), whereas they will only double in the richest economies; and China and India are expected to experience more than a sevenfold increase of their income per capita (Johansson et al., 2012). This economic convergence will in most instances coincide with a deepening of STI capabilities in emerging and developing economies. Such capabilities can be acquired in a variety of ways, notably through investments in education and R&D, which will see a growth in universities and other research centres in non-OECD settings. Connections with foreign sources of knowledge, e.g. via trade, FDI, human mobility, and R&D collaboration, are also likely to play a critical role in emerging economies' technological upgrading.

Local divergence in incomes and wealth

Inequalities within countries will pose major political, social and economic risks in the coming years. In the vast majority of advanced countries, the gap between rich and poor has reached its highest level for three decades. Today, the richest 10% of the population in the OECD area earn nearly ten times the income of the poorest 10%, up from seven times in the 1980s, though the ratio varies widely across OECD countries. In Nordic and many Continental European countries, the ratio is significantly lower than the average, but in Italy, Japan, Korea, Portugal and the United Kingdom it is closer to 10 to 1, between 13 and 16 to 1 in Greece, Israel, Turkey and the United States, and as high as between 27 and 30 to 1 in Mexico and Chile (OECD, 2015r). The working-age population, including families with children, has borne the brunt of increased inequality, consistent with rising unemployment in the last years of the period. The widening of the income distribution has been accompanied by a shift in the age profile of income poverty, with young people replacing the elderly as the group most at risk of relative poverty, a trend which began to emerge in the mid-1980s (OECD, 2015r).

The distribution of wealth is considerably more unequal than that of income, and both household wealth and its concentration have increased markedly over the last four decades. Across those OECD countries for which data are available, the top 5% and 1% wealthiest households own 37% and 18% of total household wealth respectively, while the bottom 60% of the distribution owns only 13% of total household wealth (OECD, 2016i).

Inequality undermines education opportunities for the disadvantaged, which in turn reduces social mobility, leading to a slowing of human capital accumulation. Recent analysis (e.g. Piketty and Zucman, 2013; Braconier et al., 2014) suggests that increasing inequality in incomes and wealth will very likely continue for many years to come. Indeed, based on current trends, earnings inequality in an average OECD country could rise by more than 30% by mid-century, bringing OECD countries as a whole to the same level of inequality experienced in the United States (Braconier et al., 2014). In the case of emerging and developing economies, over two-thirds of countries, encompassing 86% of the population of

the developing world, will experience growing inequalities. For many, the prospects of long-term help are particularly gloomy: by 2030, some two-thirds of the world's poor could be living in "fragile" states (ESPAS, 2015).

Insofar as technological change and innovation alter how capital and labour are deployed in an economy, they have implications for income distribution. Innovation will increase inequality given that the benefits accrue mainly to innovators and possibly also to their customers. For all actors in society to benefit, innovation diffusion is necessary. Moreover, regarding employment, most new technologies have required higher levels of skill to use than those they displace. This so-called "skill-biased technological change" has been one driver of inequality over recent decades (Paunov, 2013). On the other hand, technologies can directly promote social inclusion and economic growth. For example, digital technologies have opened up access to education through Massive Open Online Courses (MOOCs) and Open Educational Resources (OERs); connected remote populations as well as those with lower incomes to free or very low-cost knowledge and information services through low-cost mobile access; and promoted access to financial services to the "unbanked" through digital payments systems and mobile banking (OECD, 2016j). Furthermore, new concepts such as social innovation, frugal innovation, inclusive innovation, and social entrepreneurship are leading to new innovative business models and may contribute to a more inclusive approach to innovation (Paunov, 2013). These concepts blend traditional market-based approaches with solutions that address the long-term needs of societies and the environment, as well as key policy challenges, such as unemployment, poverty and climate change.

Growing levels of education

Access to education and the acquisition of knowledge and skills will be one of the most important keys to improving life chances – not only in the advanced economies, but also and especially in the developing world. The average level of educational attainment is set to rise more quickly in developing countries than in advanced economies, shrinking the gap between the two. The number of students around the globe enrolled in higher education is forecast to more than double to 262 million by 2025. Nearly all of this growth will be in the developing world, with more than half in China and India alone. As a result, by mid-century, it is possible that a majority of the world's young people will have had a university or higher-level education. In almost all OECD countries, the proportion of the population who will be graduates in 2025 is likely to increase, in some cases very significantly (OECD, 2008).

Infectious diseases

Deep dividing lines may persist for some time to come not only in respect to technology, education, income and wealth, but also and especially with regard to health. The healthcare systems of the future will have to face a growing spectrum of challenges, not least from a rapidly changing world panorama of disease. Progress has been made in the battle against some infectious diseases such as tuberculosis (TB), HIV/AIDS and malaria. HIV/AIDS mortality has fallen quite dramatically in recent years, and deaths from TB (95% of which occur in low- and middle-income countries) are declining, albeit very slowly (WHO, 2014a). Approximately half of the world's population is at risk of malaria (with 90% of malaria deaths occurring in Africa). However, between 2000 and 2013, an expansion of malaria interventions helped to reduce malaria incidence by 30% globally, and by 34% in Africa. During the same period, malaria mortality rates decreased by an estimated 47% worldwide and by 54% in

Africa (WHO, 2015). These and other interventions have seen life expectancy rates rise and converge across the world. However, trends are at work in society that suggest future progress in countering infectious diseases may become harder to achieve. Urbanisation is continuing to gather pace in the developing world; climate change is influencing geographic patterns of human and animal infections (e.g. malaria); international tourism is growing; and global migration levels are unlikely to abate.

But perhaps the most worrying trend in fighting infectious diseases is growing antimicrobial resistance. These drugs have been extensively misused in both humans and food-producing animals in ways that favour the selection and spread of resistant bacteria. The bulk of antimicrobials is given to animals. In the United States, for example, antimicrobial use in the livestock sector accounts for about 80% of total annual consumption. Between 2010 and 2030, global consumption of antimicrobials in the livestock sector is projected to increase by about 67% (Cecchini et al., 2015). With such intensive use, antibacterial drugs have become less effective or even ineffective. Furthermore, failure in antimicrobial drug discovery is contributing to the rise of global resistance. The result is an accelerating global health security emergency that is rapidly outpacing available treatment options (WHO, 2014c).

Non-communicable and neurological diseases

While the annual number of deaths due to infectious disease is projected to decline, the total annual number of deaths from non-communicable diseases (NCDs) is expected to increase from 38 million in 2012 to 52 million by 2030. This epidemic of NCDs is being driven by powerful forces such as demographic ageing, rapid unplanned urbanisation, and the globalisation of unhealthy lifestyles. While many chronic conditions develop only slowly, changes in lifestyles and behaviours are occurring rapidly and pervasively. The leading causes of NCD deaths in 2012 were cardiovascular diseases, cancers, respiratory diseases and diabetes. These four major NCDs were responsible for 82% of NCD deaths. Going forward, annual cardiovascular disease mortality is projected to increase from 17.5 million in 2012 to 22.2 million in 2030, and annual cancer deaths from 8.2 million to 12.6 million (WHO, 2014b). The prevalence of diabetes has been increasing globally in recent decades, and WHO projects that it will be the seventh-leading cause of death in 2030. NCDs already disproportionately affect low- and middle-income countries, and current projections indicate that by 2020 the largest increases in NCD mortality will occur in Africa and other low- and middle-income countries (WHO, 2011).

Cases of neurological disease, spurred in particular by rising longevity and the anticipated rapid ageing of societies in the coming decades, are expected to multiply. Alzheimer's Disease International (ADI), for example, estimates that 46.8 million people worldwide are living with dementia in 2015, and that the number will almost double every 20 years, reaching 76 million in 2030 and 135 million in 2050. Fifty-eight percent of all people with dementia live in countries currently classified by the World Bank as low- or middle-income countries. This proportion is estimated to increase to 63% in 2030 and 68% in 2050 (ADI, 2015).

Advances in medical research and technologies

Much of the extension of life expectancy and improvements in quality of living over the last century can be attributed to biomedical research and innovation that have successfully targeted life-threatening diseases and debilitating conditions. Still, the global health

challenges for the next decades are immense. But the very scale of those challenges across the developing world and the advanced economies offers vast opportunities for established and novel medical procedures, specialised treatments, new medicines and technological solutions, as well as for the development and implementation of innovative systems of health provision and care co-ordination and management. Pharmaceutical research is entering a new era of open science and use of converging technologies to uncover the genetic and biochemical underpinnings of diseases. Technological advances in DNA sequencing, omics technologies, synthetic biology, and gene editing have given researchers new tools to decipher and treat chronic NCDs (OECD, 2015i). Digital technologies – including the IoT (e.g. medical sensors, the "quantified-self" movement, etc.), big data analytics and artificial intelligence will massively increase the amounts of medical data available and enhance the power of data analysis in the service of decision-making. Robotics and neurotechnologies will also likely find extensive use in the medical field. Each of these digital technologies is discussed in Chapter 2, where many healthcare applications are highlighted. Finally, while still small-scale and marginal, do-it-yourself science groups and maker communities are likely to be increasingly visible in the healthcare field, enabled by low-cost advanced technologies like synthetic biology and additive manufacturing that allow them to research and develop their own therapeutics and medical devices.

Concluding remarks

This chapter has set out the main global megatrends that are expected to have a strong impact on societies and economies over the next 10-15 years. Considering their impacts on STI, some common themes emerge. First, the megatrends will shape future R&D agendas and the scope and scale of future innovation demand. For example, ageing societies, climate change mitigation and adaptation efforts, various health challenges, and growing digitisation are, among other factors, expected to influence the research and innovation activities carried out by firms and the public science system.

Second, the dynamics and impacts of many of these factors are international or even global in scope and call for a more internationalised framing of STI activities and policies. STI activities are already extensively internationalised, of course, e.g. through the activities of multinational enterprises and international scientific co-operation among research universities and public research institutes. Economic development in emerging economies has also seen the distribution of STI activities broaden across the globe and this is set to continue over the coming decades. STI policy, by contrast, remains overwhelmingly national in its framing. While there is often good reason for this, the scale and scope of future "grand challenges" calls for greater international STI policy co-operation, e.g. through joint programming, shared facilities, etc. that targets appropriate technology transfer and research collaboration.

Third, the megatrends suggest STI activities could be confronted with disruptive resource constraints over the next few decades. Many megatrends raise urgent issues that demand public policy responses and these could compete with STI for policy attention and resources. Furthermore, a growing, but ageing global population, together with evolving patterns of mobility and migration, will likely impact future STI labour markets.

The direction of influence is not one-way, of course, and developments in STI will shape the dynamics of megatrends and offer solutions to the challenges they raise. For example, from a shaping perspective, globalisation is enabled by advances in communications and transport technologies; future income growth will be increasingly driven by STI developments; and improved health outcomes and increasing life expectancy are heavily dependent on health technology innovation. These are among some of the beneficial impacts of STI, but there are also possible negatives. For example, STI developments could exacerbate inequalities without sufficient attention to wider diffusion and skills acquisition; and developments in artificial intelligence and robotics raise concerns around future employment opportunities. These and other impacts of STI – bearing in mind that technological change is a major megatrend in its own right – are further discussed in Chapter 2.

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