MAGYAR NEMZETI BANK

GROWTH REPORT

2019

'The true power of a nation is the number of scientifically educated citizens.'

Hitel (Credit) 178.
Count István Széchenyi

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2019

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Pursuant to Act CXXXIX of 2013 on the Magyar Nemzeti Bank, the primary objective of Hungary's central bank is to achieve and maintain price stability. Low inflation ensures higher long-term economic growth and a more predictable economic environment, and moderates the cyclical fluctuations that impact both households and companies. Without prejudice to its primary objective, the MNB supports the maintenance of the stability of the financial intermediary system, the enhancement of its resilience and its sustainable contribution to economic growth; furthermore, the MNB supports the economic policy of the government using the instruments at its disposal.

The growth trends of the economy may influence, both directly and indirectly, the ability of monetary policy to achieve the objectives set out in the MNB Act and consequently the conduct of monetary policy. Changes in the dynamics and structure of economic growth may determine the evolution of short-run inflation trends, while the longer-term growth potential and its factors can have a fundamental impact on the assessment of the financial stability of the economy. With that in mind, in the future the Magyar Nemzeti Bank will provide an annual overview of the most important trends shaping economic growth over the short, medium and longer term, presenting its assessments to members of the profession at home and abroad in its Growth Report.

The analyses in this Report were prepared under the direction of Barnabás Virág, Executive Director of the Executive Directorate Monetary Policy and Economic Analysis. The Report was prepared by staff at the MNB's Directorate Economic Forecast and Analysis, Directorate for Fiscal and Competitiveness Analysis. The Report was approved for publication by Dr György Matolcsy, Governor.

The Report also incorporates valuable input from other areas of the MNB.

Content

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Summary of key findings

The Growth Report presents a comprehensive overview of the development path of the Hungarian economy over a longer horizon and the most important factors determining this path.

The Magyar Nemzeti Bank analyses trends in economic growth in several regular publications, such as the Inflation report, the Report on the Balance of Payments, Competitiveness Report and the Financial Stability Report. These publications typically focus on the short- and medium-term developments in the economy, specifically analysing changes in variables which determine the stance of monetary policy. The objective of the annual Growth Report is to directly present the longer-term trajectory of Hungarian economic variables, sometimes over an entire business cycle, and the related critical factors, using both standard and alternative indicators. In addition to detailed examination of the available domestic data, we supplement our analyses with international and historical comparisons.

In the 2019 Growth Report, we focus on a factor **that can influence economic growth prospects over the very long term (a horizon of several decades or even centuries), covering several generations. This factor of production is the condition of the environment, i.e. the quality and volume of natural capital.** Over the past more than two centuries mankind has gone through an unprecedented economic development. As a result of this, in Europe and in America in the 19th century and in the countries of the Far East in the latter half the 20th century previously inconceivable masses emerged from extreme poverty, infant mortality decreased and life expectancy increased. However, the sudden growth observed in past decades came at a price, as consumption-centric economic growth based on the use of hydrocarbons has caused irreversible damage to the Earth’s climate and biodiversity. As a result of all this, we are currently in 24th hours, so it's time to think differently about how the world economy works.

Every year, the modern economy uses natural capital almost twice as fast as the Earth can renew it (mankind’s ecological footprint is 1.7), **resulting in an ecological deficit.** Accordingly, growth in the present structure is not sustainable, as future generations will face a reduced volume of natural resources (e.g. decreases in biodiversity, declines in reserves of certain rare earth metals) and deterioration in the quality of such resources (air pollution, natural disasters triggered by climate change, etc.). In the future, environmental factors may not only represent a scarce resource as directly used input, but the degradation of these factors (e.g. air pollution, extreme weather conditions) may also reduce the available volume and quality of other factors of production. Global warming and extreme weather anomalies have an unfavourable impact on the volume and quality of capital, while air pollution reduces the healthy years of life, increases the risk of illness, and thus also has negative impact on the labour force and the productivity thereof.

In the 2019 Growth Report, we examine the fundamental question of whether permanent growth can exist without a degradation of environmental factors. According to the optimistic school of thought, on the economic growth path the degree of environmental pollution follows an inverted U curve, referred to in the specialist literature as the ‘Kuznets curve’. Although in certain countries the degree of pollution declines in parallel with progress in development, this is mostly attributable to the cross-border outsourcing of the polluting activities, i.e. **the Kuznets curve may not actually be a global phenomenon. Thus, the process will not reverse automatically and unsustainable growth may occur, increasing real economic costs in the future.**

The results of the economic approaches and impact assessments analysing the effects of the climate vary on a wide scale. While according to the results of the classic Nordhaus economics, growth can be maintained even without an active climate policy and it supports only moderate emission reduction cycle, **the school applying the Stern approach – nowadays regarded as consensus-based – perceives the economic damages as being enormous and proposes a new green industrial revolution to support green growth**. The latest and most radical response to climate change is given by the macro ecological degrowth theories, according to which sustainability can only be achieved by changing consumer habits and reducing market competition. **One key element of green growth policy is global solutions are needed in relation to emissions limits.**

In the green growth scenario, environmentally sustainable economic growth may be achieved, which does not necessitate a drastic restraint of economic growth at a later stage. Through to 2050, at the global level annual average economic growth of 4 per cent may be forecast under such scenario, which is higher than the growth rates of 2.5 to 3 per cent projected in the alternative scenario presenting the continuation of current trends and is higher than the 30-year average (GDP growth of around 3 per cent). This may be supported by 2-per cent productivity growth for the period on average. Meanwhile, due to the progress of green industries, the economy's CO_2 emissions may decline from the current level of almost 37 billion tonnes to 20 billion tonnes. In the green growth scenario, by 2050 the ecological footprint will decline to 1.2 Earths from the present 1.7. Thus, although mankind's ecological needs would still exceed the Earth's capacities, substantial improvement could be achieved by taking the right steps. **The basic condition of this scenario is a sharp increase in green investments**: in this scenario, an **annual sum of USD 650 billion should be spent globally solely on investments fostering energy efficiency and reducing CO_2 intensity** (additional investments are also needed in the transport, agricultural, etc. sectors). Based on the calculations, on the whole the annual growth rate of green investments would need be around 5 per cent and amount to 2 per cent of GDP on average, while in the converging economies this ratio may be as high as 5 per cent of GDP. By contrast, as the available data show**, in 2018 the amount spent on enhancing energy efficiency only amounted to USD 240 billion,** while the green investment ratio was less than 1 per cent of GDP. Thus, on the whole, global commitments fell short of the desired levels, with the welcome **exception of the Republic of South Korea and China,** which at the same time also serve as an example for the other economies. **The aforementioned countries spend almost 5 per cent of their GDP on the development of green industries and have a long-term vision.**

In the 2019 Growth Report, we also examine how this can be achieved. Transition to the green growth scenario may be fostered by directed technological change both in the economic policy and at business enterprises. Directed technological change is a series of complex economic policy steps that include the diversion of the factors of production (capital and labour) and innovation toward the green economy. The role of the government is to correct market failures, hinder – through the tax policy – innovations resulting in higher greenhouse gas emissions and foster the development of green industries by elaborating a complex subsidy scheme.

Another important opportunity to achieve the green growth scenario is the collection of large volume of data and the smart use of such, i.e. big data. **In addition to enhancing corporate productivity, big data also facilitates environmentally sustainable and socially acceptable development of low CO_2 emissions, which supports the creation of environmentally friendly products, industries and business models, thereby further improving the quality of life. Expansion of the digital world and the large volume of data generated by it represent new challenge for economists, policymakers and statistical offices wishing to understand economic trends.** Data revolution accelerates the growth and generation of the volume of data, extends the range of phenomena that can be analysed and presented by data, facilitates increasingly faster availability of data, expands the range of data sources, and increases the number of data producers, processors and analysts. These changes **encourage statistical offices to modernise the traditional measurement methods and integrate the secondary data source represented by big data as much as possible.** The impact of digitalisation and technological progress appears in corporate strategies and pricing decisions, and thus also in inflation. These are the new challenges faced by the traditional measurement methodology, which should view these changes as a new opportunity.

The first condition for presenting the macroeconomic path we deem sustainable is to outline the anticipated demographic trends of the future. If we only examine current projections for global population, a further, decelerating rise in the present population of 7.7 billion can be expected, and thus the population may peak at 10.9 billion in 2100. However, if we examine the details of the process, two different trends take shape, neither of which is sustainable. **The fertility rate in the developed countries is low, which leads to decreasing population.** The process, in addition to increasing the number and ratio of dependants, imposes great burden on the welfare provision systems. **Meanwhile, fertility rate in the lower income countries is very high, resulting in extremely fast growth in population exceeding the growth rate of resources.** Due to the different demographic trends, without successful intervention the weight of the individual regions will materially change, which will redraw the currently known geopolitical maps. One example of this is that the share of European population will decrease further in world population: in 1950 European population accounted for more than one-fifth of the world population, while in 2015 only for 10 per cent, and this ratio may fall to 6 per cent by 2100. The specialist policies also try to resolve this problem. **In the developed and middle-income**

countries the government supports families and efforts to have children (as in Hungary), while developing countries try to contain unsustainable growth in population. It also raises sustainability issues that – according to the current forecasts – the population is increasing at the fastest pace in the countries and regions that are most hit by the negative impact of climate change. The process may escalate geopolitical tensions and result in rising migration pressure. For this reason, it is crucially important that the economies that face strong population growth should develop sustainable growth ecosystems that ensure the reduction of environmental burdens.

1 Environmental costs of growth

Over the past more than two centuries mankind has experienced unprecedented economic development. As a result of this, in Europe and in America during the 19th century and in the countries of the Far East in the latter half the 20th century, previously unthinkable masses emerged from extreme poverty, infant mortality decreased and life expectancy increased. However, the sudden growth observed in the past decades has come at a price, as the consumption-centric economic growth based on the use of hydrocarbons has caused irreversible damages to the Earth's climate and biodiversity.

The global warming of these days is the largest imbalance in the age of civilisation, which has become one of the biggest obstacles to long-term, sustainable growth, both at the national and global levels. So far the increase in the atmospheric concentrations of greenhouse gases has resulted in a more than 1-degree Celsius rise in the global average temperature compared to the age of industrialisation in the 19th century. As a result of warming, glaciers and polar ice caps have started to melt, accelerating the rise in the sea and ocean levels, and thus endangering the life of hundreds of millions of people and the existence of several important world economic centres. As a result of climate change, extreme weather events are occurring more and more frequently causing greater and greater damages (hurricanes, floods, droughts).

Meeting the food needs of the increasing population imposes an ever larger burden on water management and food production. The increasing number of forests destroyed to expand agricultural production may lead to further erosion of the environment, forest fires and the extinction of species. Despite the rise in the ratio of renewable resources in the industrial utilisation of energy, fossil fuels are still determinant. The ecological footprint of mankind has expanded to an unprecedented size, and since in the present economic regime, the exploitation of nature and the degree of pollution inevitably increase in parallel with development, the continuing convergence of developing countries may result in further environmental degradation in the future.

According to the scientific research, if the current trends continue, even the realisation of the objectives to reduce emissions, undertaken in the 2016 Paris Agreement, will not be sufficient to prevent that by the end of the 21st century the rise in the global average temperature does not exceed the 2-degree Celsius limit compared to the pre-industrial level. The latest results highlight the fact that carbon dioxide in the atmosphere may heat the surface of the Earth faster than previously estimated, and thus in the absence of radical changes and appropriate climate protection measures the temperature may even be 7 degrees higher by the end of the century. Accordingly, the prevention of a climate catastrophe calls for intervention as soon as possible.

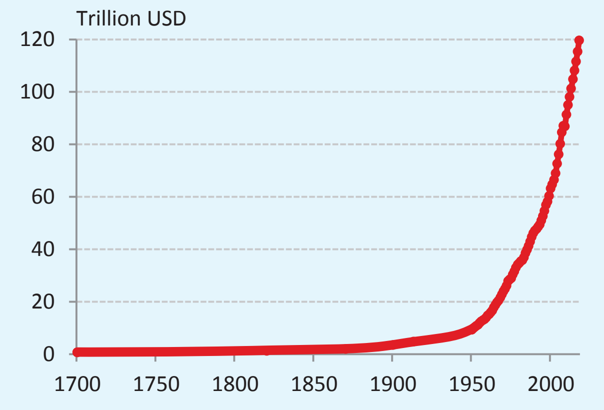
1.1 Unprecedented development in the past centuries

In the past more than two centuries mankind has experienced unprecedented economic development. The industrial revolutions of the 1800s created a series of ground-breaking technological achievements and innovations, as a result of which the functioning of the global economy, the structure of society and the lifestyle of people changed fundamentally.

As a result of the structural transformation of the economy, in Europe and America during the 19th century and in the latter half of the twentieth century particularly in the countries of the Far East, previously unthinkable masses, hundreds of millions of people emerged from extreme poverty (Sala-i-Martin, 2006).

In the past century, the size of the global economy became thirty times larger than before (Maddison, 2010) (Chart 1-1). Meanwhile, global population quadrupled, reaching 7.7 billion by 2019.

Chart 1-1: Global GDP since 1700



Note: at 2011 prices.
Source: World Bank.

As a consequence of the development, despite the demographic boom, GDP per capita also rose drastically. Based on the Maddison database**, between 1870 and current times average GDP per capita in the world rose more than tenfold**: while in 1870, calculated at 2011 prices, income per capita amounted to USD 1,263 today it is roughly USD 15,000. Although regional trends differ, economic growth can be observed in all continents. During the past 60 years, in the Sub-Saharan African region GDP per capita rose one and a half times, while more than sevenfold growth was recorded in the East Asian region (primarily in China) (Table 1-1).

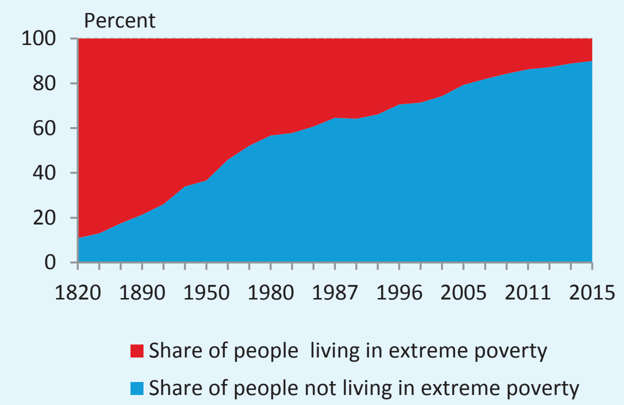
Table 1-1: Change in GDP per capita between 1960* and 2018

	1960	2018	Change
Central Europe and Baltic states	7152.7	15558.6	2.2
East-Asia and Ocenia	1283.8	9915.5	7.7
Euro area	10808.5	40248.6	3.7
Latin-America	3674.4	9377.6	2.6
Middle East and North Africa	3415.9	7741.2	2.3
North-America	17563.1	53155.2	3.0
Sub-Saharan Africa	1103.7	1652.2	1.5

*Note: *Or when data was available.*
Source: World Bank.

In parallel with this economic development, the ratio of those living in extreme poverty declined drastically. Based on the World Bank's poverty definition – according to which those living on less than USD 1.9 per day, calculated at 2011 prices, are considered as poor – since the early 1800s the ratio of the poor within the global population has fallen from almost 90 percent to below 10 percent (Chart 1-2). The global decline in poverty is strongly attributable to the fact that more and more of the world, particularly in an increasingly large part of South and East Asia, is connected to the global economy, fostering substantial economic growth (Sala-i-Martin, 2006). In China, India or Indonesia, just one or two generations ago one half of the population still lived in extreme poverty, but over a horizon of almost 30 years this ratio was halved. In the past, poverty was a phenomenon that characterised Asia, as 80 percent of the world's poor lived there; this ratio has now fallen to roughly 20 percent. At the same time, the African continent shifted in an opposite direction than the Asian development, and by now 75 percent of the world's poor live in Africa.

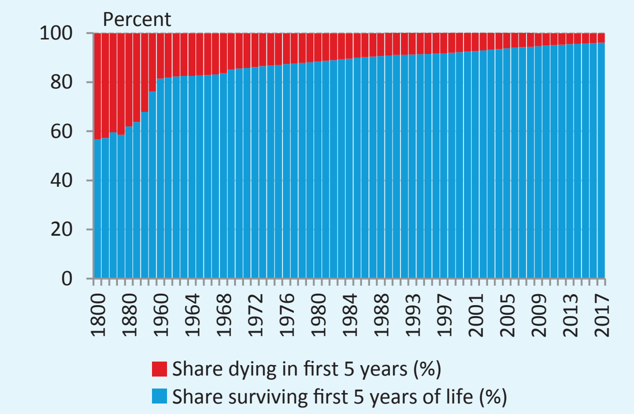
Chart 1-2: Ratio of those living in extreme poverty



Source: World Bank.

In parallel with the development and improvements in healthcare and education, global infant mortality has also been on the decline for decades. In previous centuries, infant mortality was a major problem: in the 19th century in Germany only every second infant reached the age of 5, while this ratio in Sweden was two out of three. At the beginning of the 1800s, more than 40 percent of the world's infants died before the age of 5, but by 1960 this ratio had fallen to below 20 percent – i.e. fewer than one of every five children died before the age of 5. This ratio has now fallen to below 4 percent, and thus in the span of 200 years the infant mortality rate dropped to almost one-tenth; moreover, in the developed countries this ratio is below 1 percent (Chart 1-3).

Chart 1-3: Global infant mortality

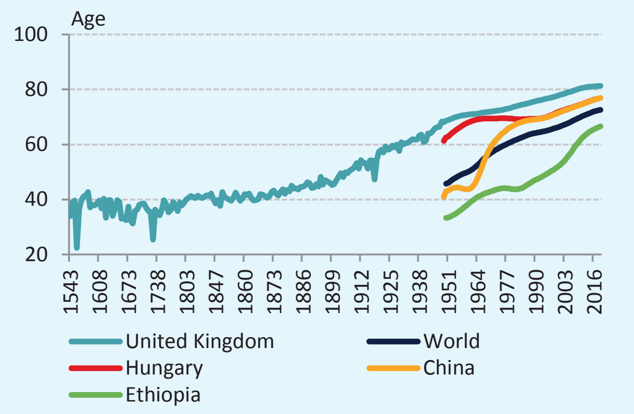


Note: Ratio of those deceased/survived in the first 5 years of their life.
Source: World Bank.

The biggest improvement was achieved in the large developing countries. For example, in China and Brazil in the span of 40 years infant mortality declined to one-tenth of its previous level. In other developing countries – particularly in Africa – the mortality rate is still high, but improvement can be observed in these countries as well.

Similar trends can be identified also in life expectancy. For example, in the United Kingdom – for which we have the longest time series – the life expectancy of around 40 years in the 16th century doubled and today it is over 80 years. This trend can be identified globally, and even separately for the developing world. Global life expectancy is around 72 years on average, while in China it is even higher, at almost 77 years (Chart 1-4). In Ethiopia life expectancy was only around 30 years in the middle of the 20th century, but it now exceeds 65 years. When examining life expectancy by gender, we found that the value rose substantially for both men and women. Compared to 1960, the life expectancy of women and men rose from 54 to 74 years and from 50 to 70 years, respectively.

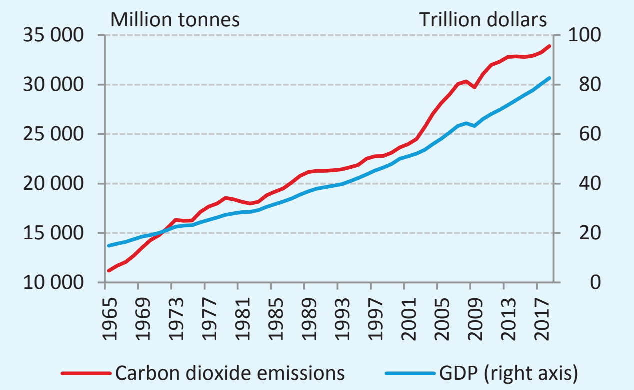
Chart 1-4: Life expectancy



Source: United Nations Economic and Social Council.

However, the sudden growth observed in past decades and integration of developing countries into the global economy has had a price. As a result of the structural transformation, radical growth was first based on the industrial and then on the services sector. This accomplishment was accompanied by an expansion of the hydrocarbon-based economy (Chart 1-5). **Industrialisation-based, consumption-centric economic growth caused irreversible damages in the functioning of Earth and the climate.**

Chart 1-5: Global GDP and global carbon dioxide emissions



Source: EEA, World Bank.

1.2 Environmental costs of development

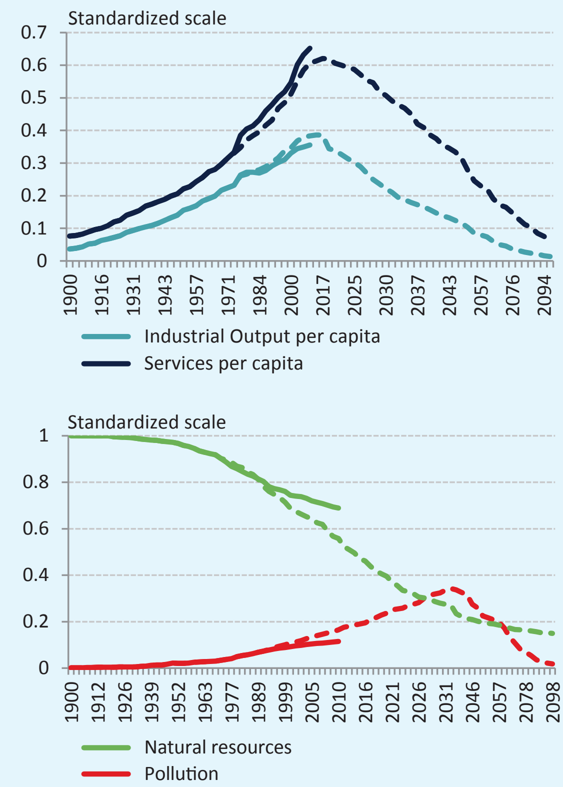
Today's warming marks the greatest temperature deviation in the period of civilisation: since the existence of the *homo sapiens* no such major climate change has occurred. The last time when the temperature on Earth was 2-3 degrees Celsius higher and the sea level was about 10-20 meters higher was about 3 million years ago. **During the past 10 thousand years of civilisation, compared to the industrialisation period the temperature always fluctuated by +/-1 degree Celsius.** According to some analyses, based on the current functioning of the economy, and our production and consumption habits, by the end of this century, i.e. by 2100, the temperature will be 3 degrees Celsius higher (Oswald and Stern, 2019). **Climate change may become one of the most important obstacles to long-term sustainable development both at the national and global levels.**

The ecological footprint of mankind rose to an unprecedented degree, and the atmospheric concentration ratio of greenhouse gases is increasing. **Compared to the age of industrialisation, which serves as a benchmark, global average temperature has now risen by more than 1 degree Celsius**, accelerating the melting of ice caps and glaciers, causing sea levels to rise and increasing the frequency and intensity of storms, droughts and floods. **Climate change also generates a number of local impacts.** Increasingly frequent storms and extreme weather conditions lead to the extinction of forests, record numbers of forest fires or floods of formerly unseen magnitude in the western world. The unbearable heat, droughts and the frustration of agricultural production results in desertification in the Middle East and Africa, and contributes to the destabilisation of global security.

As early as the 1980s, the United Nations recognised that the finiteness of environmental resources and the degradation of nature hinder development in the long run. In its 1987 report entitled "*Our Common Future*", the Brundtland Commission pressed for a new era of economic growth and set as a target "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs".*[1] In the publication, it is emphasised that the key trigger of climate change is human activity; nevertheless, most countries still focus on economic growth in the traditional sense.

In respect of these issues, **economic projections have also been available since the 1970s**, the results of which, however, include a large degree of uncertainty and depend strongly on the assumptions applied. The report entitled *"The limits to growth"*, edited by Donella H. Meadows et al., was the first technical projection of the impact of exponential economic and population growth on natural resources. **Based on their simulations, if the growth model prevailing at that time (that is still regarded as mainstream at the global level)** which is based on exploiting the environment **continues, the Earth will run into its production constraints by 2072**, and suddenly an uncontrolled decline will commence both in the population and productive capacity (Chart 1-6). Three decades later, Turner (2008), using the additional data of 30 years, re-estimates the model created by Meadows et al., **and confirms the earlier projection: he finds that the global economy has continued to follow the resource-absorbing and polluting path observed in the 1970s** (Chart 1-6). **Kenneth Boulding, British economist, writes in his hit book entitled "The Economics of the Coming Spaceship Earth" about two types of economy. The first type is the cowboy**, according to which resources do not exhaust: one only needs to change location and continue the previous activities. According to this theory – which may be interpreted as the philosophy of industrialised countries – consumption and production are positive phenomena under all circumstances. **By contrast, the spaceship economy has its constraints both in terms of exploitation** and pollution, and thus mankind – considering the ecological system – should optimise rather than maximise output, depending on the harmful externalities and the exhaustion of resources.

Chart 1-6: Comparison of the scenarios from 1972 and 2008



Note: The dotted line represents the results of the 1972 estimate, while the solid line shows the results of the 2008 estimate.
Source: Meadows 1972, Turner 2008.

As result of environmental sustainability, the question of social sustainability has also become an increasingly

1 Our Common Future, 1987

important problem. As a consequence of climate change, food production is becoming impossible in an increasing number of regions. Agricultural crop yields may decline substantially in areas turning into desert as a result of the rise in the average temperature, extreme weather conditions becoming increasingly frequent and intense, changes in rain and drought patterns and changes in the biosphere. Based on the forecasts, **desertification has the strongest impacts on regions where the population has increased to the largest degree** (for more details on this see Section 6).

Demographers and economists have been concerned about the interlinking of population and resources (in a classic case food production capacities) since the work of Malthus (1798). According to the theory of the *"Study on the Laws of Population Growth"*, while population increases exponentially, doubling every 25 years, the production of food may rise only linearly. Insufficient food production causes global famine, which results first in decreasing population and later in an end to growth. At the same time, the forecast of Malthus did not come true due to the achievements of the industrial revolution of the 19th century and progress in new agricultural technologies.

In addition to unsustainable global growth and changes in the biosphere resulting from climate change, additional ecological factors (access to clean potable water and clean air) may increasingly hinder economic activity. The world famous book of Jared Diamond (2005) entitled "Collapse", describes the connection between fast population growth and the erosion of the environment, based on the case of Ruanda, one of the most densely populated countries in the developing world. Diamond interprets the genocide of the 1990s within the context of this: due to the failure to modernise agricultural production, by 1993 in one of the world's most densely populated countries the median size of farms fell to 0.7 acre, while in the same period, in Montana state the farm size necessary for the sufficient support of a family was around 40 acres. In parallel with the decreasing cropland per capita, due to the demographic boom, the daily average calorie intake fell below 1,600 calories – representing the famine threshold – among more than 40 percent of the population. In addition to the aforementioned reasons, climate change and unpredictable crop yields exacerbated tribal conflicts, which led to one of the bloodiest genocides of the 20th century.

In the following, we first review the degree of environmental degradation to date and the related sustainability issues, highlighting the long-term unsustainability of the present social and economic system's growth model.

1.3 Current condition of natural resources

An average person on Earth produces roughly 5 tonnes of carbon dioxide (CO_2) annually, about one quarter of which remains in the atmosphere for more than one thousand years, and together with the greenhouse gases, substantially distorts the planet's energy balance (Le Quéré et al. 2018, Archer et al. 2009). Carbon dioxide is an essential requisite of human life and the development of flora and fauna. In a state of equilibrium, the ratio of the Earth's carbon dioxide emissions and capture is identical. The sunlight reaching the surface of Earth is later reflected back into space as heat. However, greenhouse gases in the atmosphere block part of this reflection, and thus infrared lights are once again reflected back to the surface of Earth, increasing the temperature. The presence of greenhouse gases is essential for life on Earth, because without such gases the temperature of the surface of earth would be too cold and unsuitable for life. However, as a result of human activities, the atmospheric concentration of greenhouse gases has already reached such a high level that it is upsetting the state of equilibrium.

As a result of a 1 percent increase in the concentration of atmospheric carbon dioxide, roughly 27 trillion watts of energy is reflected back to the surface of the Earth every two seconds, which corresponds to the energy of a nuclear bomb of the size of Hiroshima. The climate changes stemming from the reflected heat, influence the temperature of the surface of the Earth, and also determine the height of the sea level, the formation of clouds, the locations of hurricanes and the timing of rains and floods.

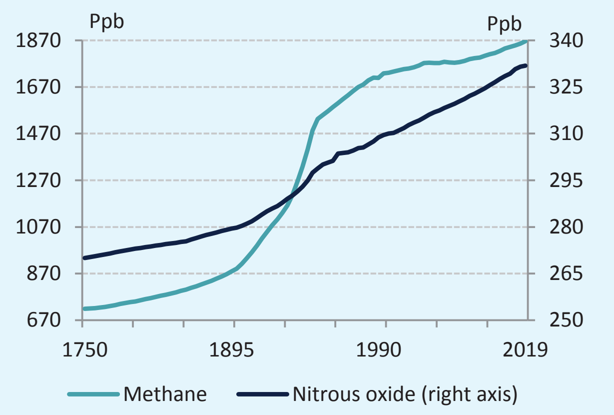
By the 20th century, practically all economically valuable activity results, either directly or indirectly, in the emission of greenhouse gases, which fundamentally determines climate developments. As a result of its numerous interventions, mankind is risking the health of nature and our environment. Emissions of greenhouse gases – such as carbon dioxide, methane, nitrous oxide and gases of fluorine content – into the atmosphere, the use of chemical substances or changing the use of the soil, deforestation, or the destruction of the habitat of many creatures and species, all result in a rise in the atmospheric concentration ratio of harmful substances and in the pollution of soil and waters. **Due to the economic activity of humans, the balance of our environment is breaking down, but it is extremely important to safeguard the biological and geophysical resources necessary for human life.**

In the following, we review the current situation with regard to key natural resources. In addition, we also touch upon climate change forecast prepared by the UN, based on which – if the present growth pattern remains in place – carbon dioxide emissions will rise significantly, while global average temperature may increase by 4 degrees.

1.3.1 AIR

The atmospheric concentration of greenhouse gases started to rise steeply after the second industrial revolution. Nitrous oxide in the atmosphere has risen by more than 20 percent since 1750, while the level of methane already doubled by 1975 and has been rising ever since (Chart 1-7).

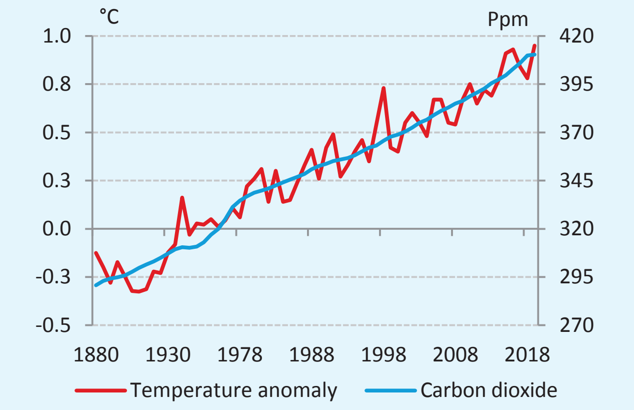
Chart 1-7: Atmospheric concentration of methane and nitrous oxide



Note: Data in parts per billion (ppb).
Source: European Environment Agency (EEA), 2 Degrees Institute.

However, carbon dioxide emissions account for the largest part of greenhouse gases. The atmospheric concentration of **carbon dioxide** started to rise in the second half of the 19th century, and it **undoubtedly contributes to the increase in average temperature.** The global average temperature has been deviating upwards from the average of the 20th century for decades and the degree of deviation is becoming more and more significant (Chart 1-8).

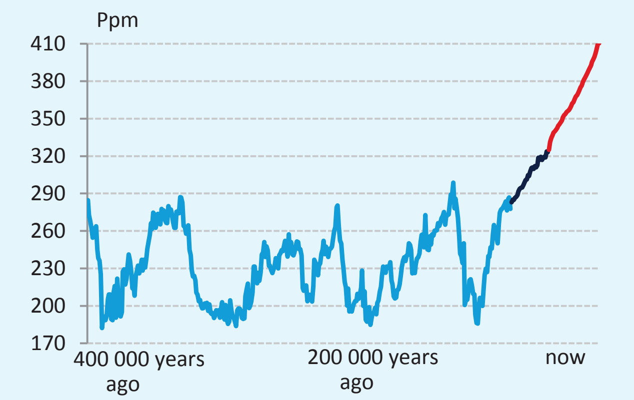
Chart 1-8: Temperature anomaly and changes in the carbon dioxide atmospheric concentration ratio



Note: The temperature anomaly represents the deviation from the average of the 20th century. Data for the carbon dioxide atmospheric concentration are in parts per million (ppm).
Source: EEA, 2 Degrees Institute, National Oceanic and Atmospheric Administration (NOAA).

The atmospheric concentration of carbon dioxide has risen to extreme heights in a historic comparison as well. In the past more than 400 thousand years, the level of carbon dioxide in the atmosphere did not reach 300 parts per million (ppm), whereas today it is already over 400 parts per million (Chart 1-9). The last time the atmospheric concentration of carbon dioxide was similarly high as today, the surface of Earth must have looked completely different: it was warmer by 3 degrees Celsius on average, there was no ice on Greenland and part of Antarctica was covered by forests. The ice covering these areas was present in the form of water in the oceans, which was coupled with a sea level roughly by 20 meters higher than now (The Economist, 2019b). **Thus, it is difficult to forecast the consequences of such a high level of atmospheric carbon dioxide concentration, and it may have irreversible effects.**

Chart 1-9: Carbon dioxide atmospheric concentration in historic terms

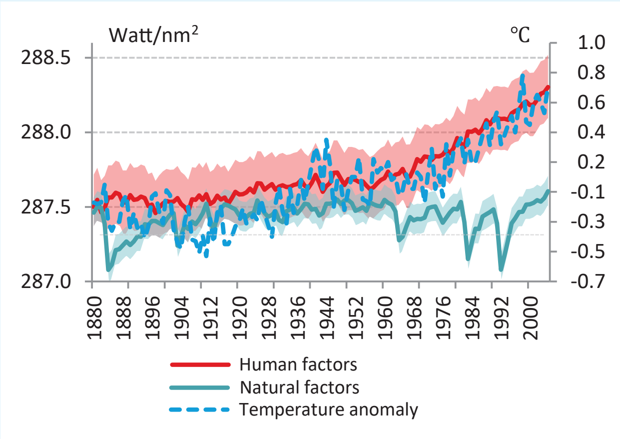


Note: Data in parts per million (ppm).
Source: CDIAC, NOAA.

Previously, there were doubts about the causes of the climate change, but the scientific community now agrees that **human activity may have the largest influence on global warming**[2] (Chart 1-10). The role of natural factors causing the change in the global average temperature can be calculated based on the data of the National Oceanic and Atmospheric Administration. Examining the time series of the century and a half since 1880 we find that although warming occurred over the entire time frame, the rise in temperatures has accelerated markedly only from 1970 and since then each decade has been warmer than the previous (League et al., 2019). Since the energy output of natural factors is constant over almost the entire period, human activity can be assumed to play the determinant role in climate change (The Economist, 2019b).

According to the latest UN data, July 2019 was the warmest month ever, while the 5-year period 2015-2019 may be the warmest period to date since comparative data are available (i.e. since 1850), exceeding the pre-industrialisation average by 1.1 degree Celsius and the period 2011-2015 by 0.2 degree Celsius (League et al., 2019).

Chart 1-10: Change in global average temperature



Note: The bands show the uncertainty of +/- one standard deviation. The watt/m2 is a measurement unit for radiative forcing, used for measuring the impact of greenhouse gases intensifying warming.
Source: Bloomberg, NOAA.

Based on the forecast models, it is most likely that global warming will continue until the rise in the atmospheric concentration of greenhouse gases stops. In order to ensure that the rise in the global average temperature does not exceed the limit of 1.5 degree Celsius – which is the objective of the **Paris climate protection agreement, which entered into force in 2016** – the volume of carbon dioxide in the atmosphere may be a maximum of 2.8 trillion metric tonnes. This is the "carbon budget" of mankind. By 2018 we had already used roughly 80 percent of this. In the past decade alone, emissions amounted to almost 400 billion metric tonnes. In order to keep global warming below 1.5 degrees, by the middle of the 21st century carbon dioxide emissions must be reduced to zero (Borunda, 2018), which means that by 2030 the current emissions level should be halved. Based on the present projections, no country is able to fulfil this (The Economist, 2019b): **Moreover, even zero emissions do not reduce the carbon dioxide present in the atmosphere; this would require technologies that are able to extract carbon dioxide from the atmosphere.**

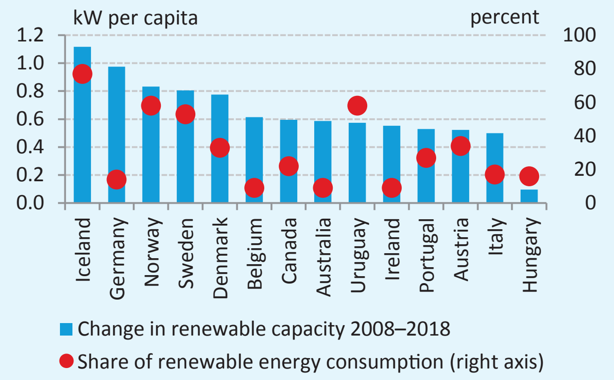
Reducing emissions of **greenhouse gases** (primarily carbon dioxide), dust and other pollutants into the atmosphere **is not possible without changing energy consumption.**

Fossil fuels currently account for more than 80 percent of energy consumption. According to calculations by Aengenheyster et al. (2018), in order to prevent the global average temperature increase from exceeding 1.5 degrees Celsius by 2100, the **ratio of renewable energy sources would have to rise annually by 2 percentage points** and one half of energy consumption should be provided from renewable resources by 2038. However, in the past decades average growth has only amounted to 0.1 percentage point.

Replacing fossil fuels is not a simple task. The European Union pays special attention to environmental protection. In the past decade, Germany installed more than 1 kilowatt renewable energy generating capacity per capita owing to the wide-ranging introduction of wind and solar energy, and several other EU countries are also in the vanguard of building renewable capacities (Chart 1-11). **Among these Hungary can also be highlighted, since – based on the latest data – the 2020 commitments are already fulfilled, while nearly 15 percent of the energy consumption comes from renewable resources.**

2 Although some people still dispute the anthropogenic origin of climate change (Miskolczi, 2010; NIPCC, 2013), the vast majority of the scientific community agrees that climate change can be attributed to the warming effect of the greenhouse gases emitted by mankind (Benestad et al., 2016).

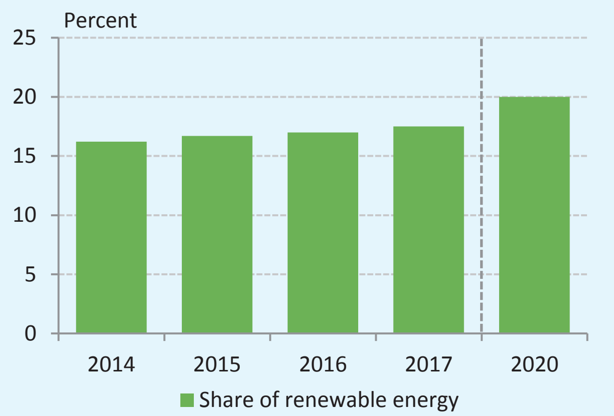
Chart 1-11: Development of renewable energy generation capacity between 2008 and 2018



Source: IRENA (2019), WDI.

The ratio of renewable resources is continuously rising in the energy consumption of EU member states (Chart 1-12). However, despite the deployment of capacities, the growth rate still falls short of the aforementioned value of 2 percentage points.

Chart 1-12: Ratio of renewable energy in the EU's energy consumption

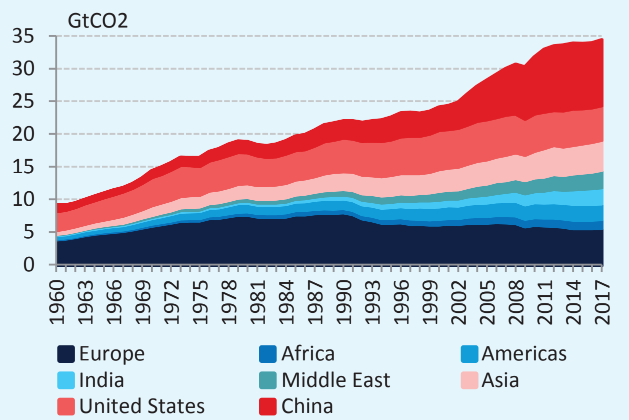


Source: Eurostat (2019).

In a breakdown by industries, the **energy sector is the largest carbon dioxide emitter**: in 2016 it emitted more than 15 billion tonnes of gas into the atmosphere, and thus it accounts for almost 40 percent of total carbon dioxide emissions. Although globally the **carbon dioxide emissions** of the energy sector **as a percentage of GDP essentially remained unchanged at a level of 0.2 kg CO_2/US$ GDP, major differences can be identified between the regions of the world**. In the EU countries, the carbon dioxide intensity of the sector fell by more than 30 percent. The downward trend is a general phenomenon in the developed countries, but this is offset by the emerging countries' increasing energy intensity at the global level. At the same time, transportation and industry also substantially contribute to the continuous rise in carbon dioxide emissions (IEA, 2018). **The transportation sector accounted for 20-24 percent of the world's carbon dioxide emissions. Moreover, this sector's carbon dioxide emissions have more than doubled since 1970, rising faster than in any other energy end-user sector.** In 2016, its carbon dioxide emissions reached as high as 8 gigatonnes, 74 percent of which is attributable to road transport, 12 percent to air traffic and 11 percent to water traffic. Industrial production emits sulphur dioxide and other toxic smoke into the environment by burning fossil fuels. **Industry accounted for almost 20-25 percent of the world's carbon dioxide emissions, and this sector also accounts for more than one third of the world's electricity consumption.**

In a breakdown by country, the largest emitter is China, followed by the United States, India, Russia and Japan (Chart 1-13). These five countries together accounted for more than half of the world's carbon dioxide emission in 2017, while the **15 largest emitter countries accounted for more than 70 percent of global emissions** (Fleming, 2019). The carbon dioxide emissions of Hungary amounted to nearly 65 million tonnes in 2018 (showing a downward trend), accounting for 1.4 percent of total EU emissions.

Chart 1-13: Carbon dioxide emissions by country/region



Note: America without the United States, Asia without China and India
Source: Carbon Dioxide Information Analysis Centre (CDIAC), United Nations Framework Convention on Climate Change (UNFCCC), BP (2017).

Reducing air pollution is important not only for the purpose of mitigating global warming, but also for the protection of health, since curbing emissions of pollutants may also reduce the rates of death and disease related to air pollution. Based on the data of WHO, **more than 80 percent of the urban population is exposed to higher air pollution than the permitted limit** and 4.2 million people die annually due to reasons attributable to outdoor air pollution (WHO, 2019). Moreover, according to their estimates, **93 percent of the world's 1.8 billion children**

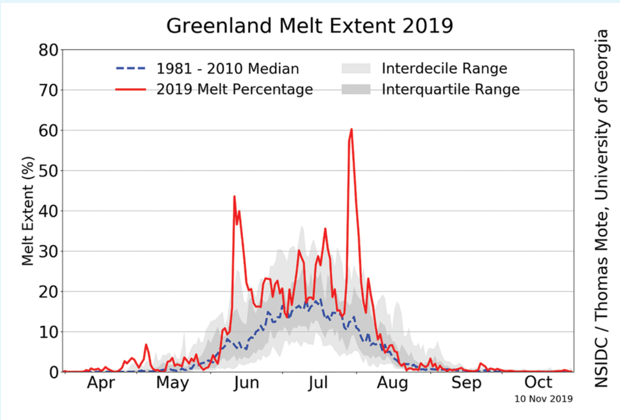
live in an environment where the air is polluted, 630 million of whom are below the age of 5. However, the developed countries are not exceptions to this either, since according to WHO the living conditions of more than one half of the children are characterised by sub-standard quality air.

1.3.2 WATER

Water is definitely one of the most important natural resources, which is indispensable for the survival of mankind. Although most of our planet is covered by water, only 2-3 percent of this is fresh water and a large part of this is present on Earth in the form of snow, ice or glaciers.

In parallel with the rise in average temperature, the polar ice sheets are melting at a faster rate than ever before. This year, **melting affected a larger area of the Greenland ice sheet than the median of previous decades** (Chart 1-14). Due to the mild winter and early thaw, the size of the areas that started to melt this year and the total ice sheet mass loss approached the record level registered in 2012.[3]

Chart 1-14: Extent of ice sheet melting in Greenland

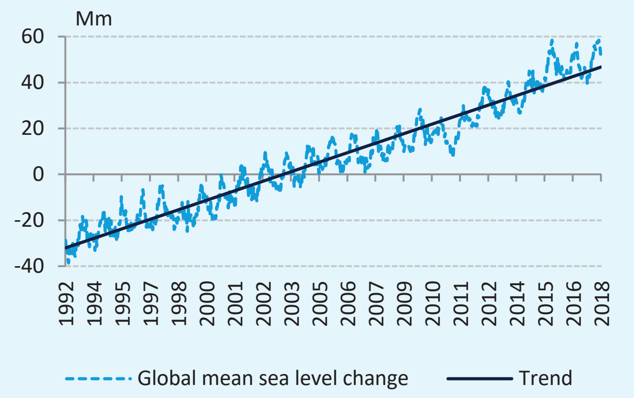


Source: National Snow & Ice Data Centre (NSIDC).

Melting ice sheets contribute to the rise in sea levels. The average change in global sea levels has been fluctuating in the positive range for years and is moving on a continuous upward trend (Chart 1-15). **The global average temperature, which exceeds** the pre-industrialisation level **by 4 degrees Celsius may also cause sea levels to rise by 2 metres**, risking the displacement of more than 180 million people in densely populated coastal areas.[4] Rising sea levels not only endanger the smaller islands, but also major commercial and financial centres, such as New York or Tokyo. 40 percent of the US population live in the coastal areas of the United States and more than 45 percent of the country's GDP is produced there (NOAA, 2017).

However, melting is dangerous not only in terms of the rise in sea levels: with the **melting of permanently frozen soil, methane is released, i.e. the atmospheric concentration of greenhouse gases increases, contributing to the rise in the global average temperature.**

Chart 1-15: Change in average global sea level



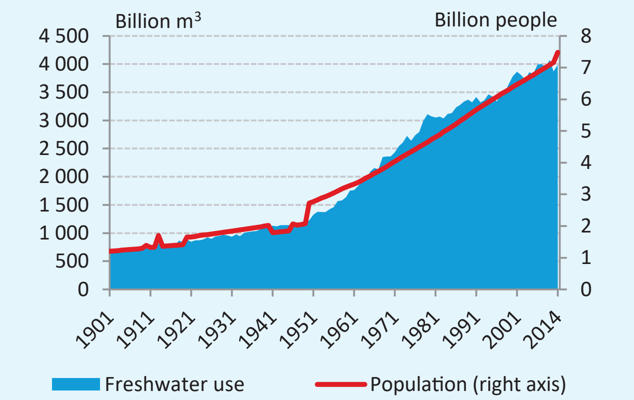
Note: Compared to the sea level in 1900.
Source: 2 Degrees Institute.

Ultimately, climate change influences the volume of precipitation and thus not only affects sea levels, but also the water level of rivers. As a result of the changing climate, **floods may occur more frequently and affect larger areas**; cloudbursts may take place, also contributing to floods. **Due to floods and increased precipitation, soil erosion may increase**, possibly jeopardising agricultural production and thereby the food supply and habitation of millions in a number of areas.

In 1901, fresh water consumption amounted to 671 billion m^3, which increased in parallel with the rise in population to reach 4,000 billion m^3 per year in 2007 and has remained at a similar level since then (Chart 1-16).

3 NSIDC (2019)
4 Nicholls et al. (2011)

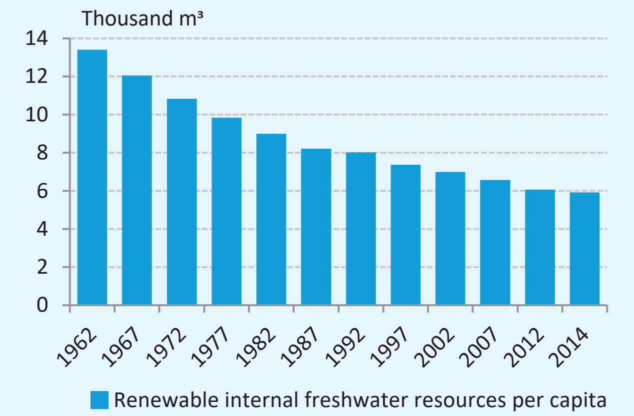
Chart 1-16: Fresh water consumption and population



Source: WDI, Maddison.

However, **the growth in fresh water reserves is unable to keep up the pace with the needs of the exponentially growing population, predominantly in the developing world**, and thus the renewable internal fresh water supply per person is continuously decreasing. In 1962, this value was still more than 13,000 m³, while in 2014 it was less than half thereof, below 6,000 m³ (Chart 1-17).

Chart 1-17: Renewable internal fresh water resources per person



Source: WDI, Global International Geosphere-Biosphere Programme (IGBP).

Water shortage is now a major challenge in several locations around the world. Based on WHO and UNICEF data, more than one quarter of the global population has no access to clean potable water. **Although great progress has been made, the supply of 2.2 billion people with clean potable water is still unresolved** (Ritter, 2019)**.**

Water shortages do not only affect developing countries and are not limited to underdeveloped areas. A 2014 survey examined the five hundred largest cities of the world and found that **one in four cities is threatened by water shortage.** The most threatened locations include Sao Paolo, Beijing and Cairo, as well as developed cities such as London, Tokyo and Miami (BBC, 2018).

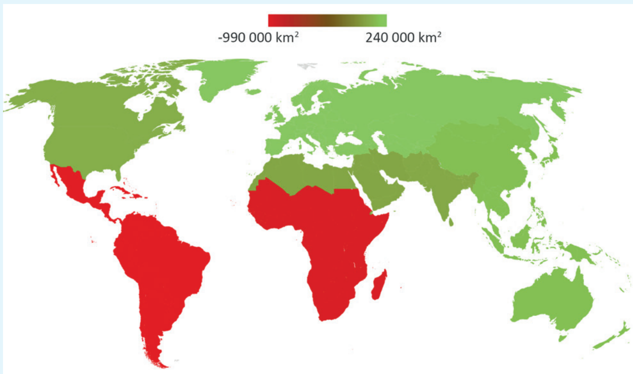
Satisfying global water demand also depends strongly on the unsustainable exploitation of subsurface water resources. Overconsumption of water may jeopardise aquifers and increase saltwater intrusion in coastal areas, which may substantially deteriorate water quality. In line with the decrease in water reserves, national and global conflicts may become more frequent (The Economist, 2019a).

1.3.3 FORESTS, HABITATS AND BIODIVERSITY

Forests play a key role in the global biosphere processes. **In addition to their capacity to absorb carbon and produce oxygen, they provide habitats for many species and help reduce flooding and soil erosion.** Forests contribute to protecting the purity of water, air and soil. Furthermore, the vegetation is able to regulate the soil water storage capacity and also fosters the self-purification of rivers (Bakó, 2018), and thus forests are of utmost importance also in terms of the climate and the protection of ecosystems.

At the same time, despite their importance, large-scale deforestation is occurring in a number of areas. **Between 1990 and 2016, the area of territories covered by forests declined by more than one million square kilometres globally.** Although the area of forests increased on several continents (North America, Europe, Asia, Australia), deforestation and forest fires in South America and Africa affected such large areas that it resulted in a decrease globally (Chart 1-18).

Chart 1-18: Change in the territory of areas covered by forests between 1990 and 2016



Note: data in km2
Source: WDI.

The protection of forests is complicated by the fact that wood is a valuable commodity, used in large volumes in several fields of the economy. Today, with a view to reducing plastic pollution, many shops have replaced packaging materials with paper, but this has negative effect on forests.

Alternatively, such packaging may be made of recycled paper, but the production of recycled paper uses large volumes of water, and thus it also cannot be regarded as environmentally-friendly packaging material.

The decline in the areas covered by forests is attributable to a great degree to the rise in the world's food demand. The exponentially growing population in the developing world results in rising demand for food, the satisfaction of which necessitates the agricultural cultivation of an increasing area. Part of the Amazon rainforest fires arose as a result of deforestation by burning, since in this way farmers gain new areas where they can grow plants and breed livestock. However, these areas are of poor quality, less suitable for agricultural cultivation, and thus they soon become exhausted.

The focus of technological innovations in the area of agriculture should be – in addition to improving and maintaining soil quality – on realising higher crop yields on the same or smaller areas, since this is the only way to protect woodlands.

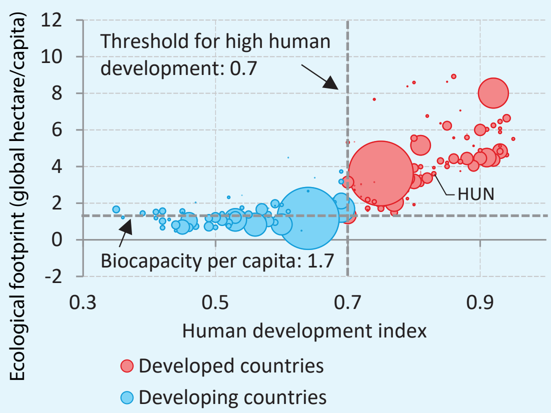
Human activity (overhunting, overfishing), the destruction of habitats (deforestation), pollution, climate change and the spread of invasive species are all factors that contribute to the fact that **at present we are witnessing the sixth wave of extinction in the history of Earth, which is more intensive than ever before.** Several hundreds of species are disappearing from the planet each year and their extinction is taking place much faster than previously assumed. Experts examined the decrease in the number of organisms of 27,600 birds, amphibians, mammals and reptiles – accounting for half of the vertebrates – and examined separately the changes in the population of 177 mammal species between 1990 and 2015. They found that more than 30 percent of the vertebrates declined both in terms of population and geographical distribution. Experts found that the decline in the number of organisms affects the most animals in the southern and south-eastern parts of Asia. **The major decline in biodiversity have severe ecological, economic and social consequences,** since **the existence of mankind greatly depends on biological processes** (Ceballos – Ehrlich – Dirzo, 2017).

1.3.4 ECOLOGICAL FOOTPRINT

The ecological footprint measures the size of land and volume of water that a given population requires to produce the natural resources it consumes and to absorb its waste. With today's trends of increasing population and consumption habits, the optimal value – representing sustainability – would be 1.7 hectares per person on average. However, on average, one person uses 2.8 hectares, i.e. well above the sustainability threshold. **The size of the ecological footprint indicates that the present global growth is damaging our non-renewable resources to such a degree that cannot continue in the long run, i.e. it is unsustainable.**

There is a positive relation between the development level of the countries and the ecological footprint (Chart 1-19). It is primarily the ecological footprint of the countries classified as developed based on the human development index (HDI) that exceeds the sustainability threshold, while most of the developing countries are below the limit of 1.7 global hectares/person. Unfortunately, the ecological footprint of Hungary is far above the global average and stands at 3.6 global hectares/person.

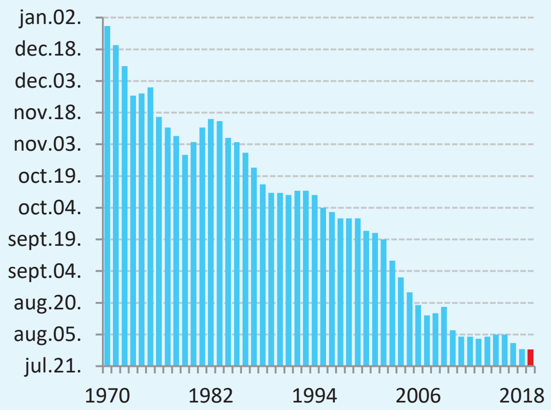
Chart 1-19: Correlation between the ecological footprint and the level of development



Note: The size of the bubble shows the size of the population.
Source: Global Footprint Network (2019).

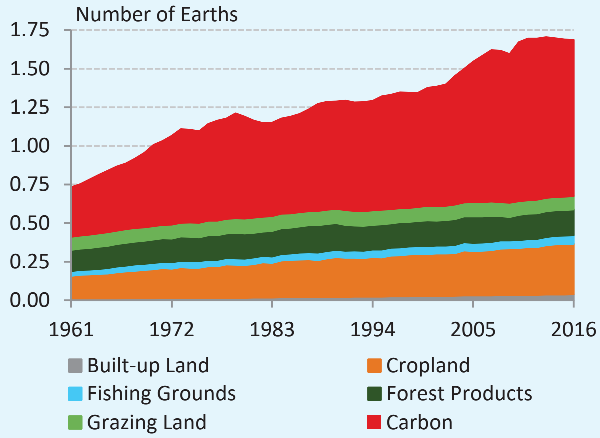
Another method of measuring ecological footprint is the determination of the overshoot day. This is the day when humankind's resource consumption for the year exceeds the Earth's capacity to regenerate those resources that year. **Since the 1970s, every year the Earth overshoot day falls on an earlier date**: this year it was 29 July, which falls short of the 2018 value by two days (Chart 1-20). **After this date, consumption already results in degradation of the ecosystem.**

Chart 1-20: Earth overshoot day



Source: Global Footprint Network (2019).

Chart 1-21: Decomposition of the ecological footprint



Source: Global Footprint Network (2019).

The sustainability threshold would be 1; in this case, humanity would use exactly as much resources as the planet is able to provide. However, **maintaining the current level of human activity would require resources that an Earth larger by 1.7 times would be able to provide.**

Based on the decomposition of the ecological footprint, it is clear that **the sustainability thresholds are exceeded due to the large-scale carbon dioxide emissions.** In 2016, absorbing the **carbon dioxide emissions produced from the use of fossil fuels already required the area of one entire Earth**, which exceeds the size of the areas necessary for pursuing all other activities (e.g. agricultural production or fishing) (Chart 1-21).

Until 1970, humanity accumulated ecological reserves, i.e. used less resources than the bio-capacity of Earth. However, since then **an ecological deficit has been accumulated on a continuous basis**, i.e. the present generations satisfy their own needs to the detriment of future generations. **This practice will result in the exhaustion of natural resources**, due to which the significant economic growth observed in the previous decades cannot be maintained in the future.

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2 Ecological constraints of production opportunities and the growth path achievable by managing them

Up to now, the growth prospects of the global economy have not been hindered by the deteriorating condition of environmental components. Our ecological footprint 1.7 times the size of the Earth implies that either the capacities of the ecosphere and the level of non-renewable resource have not been assessed correctly, or that the unfavourable effects will appear later in time, thereby making the lives of our children and grandchildren more difficult. In such an ecological, social and economic system, in which human (economic) activity functions on Earth, the time required for feedback is long, and thus in the near future the decline in natural capital will represent an increasingly more significant constraint for production. Environmental factors not only may represent scarce resource as directly used inputs, the degradation (air pollution, extreme weather conditions resulting from global warming) of such factors may also reduce the available volume and quality of the other factors of production.

Looking ahead, according to an optimistic school, on the path of economic growth the degree of pollution follows an inverted U curve, referred to by the literature as the environmental Kuznets curve. This is essentially caused by three factors: production in larger volume alone increases pollution; however, in theory the process is sooner or later offset by the transformation of the structure of the economy, i.e. progress in the services sector and the pollutant emission rate will decrease as a result of innovations. Unfortunately, the data show that although in certain countries (including Hungary) the degree of pollution is declining in parallel with progress in development, this is mostly attributable to the cross-border outsourcing of polluting activities, i.e. the environmental Kuznets curve is not a global phenomenon.

Based on the literature and available estimates, the current economic growth path observed globally is not sustainable ecologically, since it takes place in conjunction with a drastic degradation of nature. With materialisation of the green scenario, a sustainable green economic pattern will become feasible, which does not necessitate curbing the economy. However, one essential condition for this is a boom in significant investments in clean technologies, reaching at least 2 percent of GDP. In the green growth scenario, real GDP may grow at an average annual rate of 4 percent until 2050. Such growth scenario may be supported by a productivity growth of around 2 percent. Meanwhile, due to the development of green industries, the CO2 emissions of the economy may decline from the present level of almost 37 billion tonnes to 20 billion tonnes. In the green growth scenario, by 2050, the ecological footprint will decline to 1.2 Earths, from the current 1.7. Thus, although the ecological needs of mankind still exceed the Earth’s capacity, substantial improvement could be achieved by taking the right steps.

2.1 Ecological constraints of production opportunities

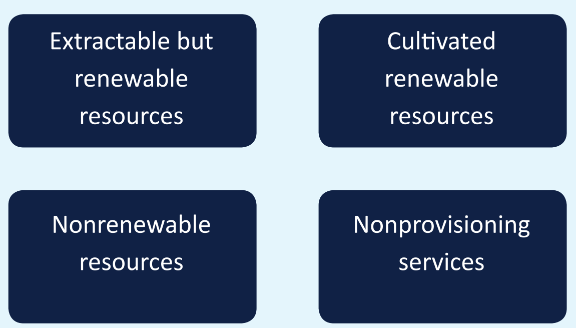
Exceeding the global ecological footprint of 1 raises important questions in relation to the sustainability of economic development. **The degradation of environmental factors, and the impact thereof on the real economy and welfare, is a process that unfolds extremely slowly.** The full impact on humanity, society and economy often may only be perceived after decades or even a full century. It should be examined whether **the natural resources are also available for future generations**, to ensure that they can also live in welfare and prosperity.

On the other hand, the **environmental factors**, i.e. the natural capital is not only an important input in production, **it is also the medium of human life and economic activity**. Accordingly, **the degradation and deterioration of environmental elements may deteriorate the growth contribution of other physical production factors** (physical capital, labour, productivity).

2.1.1 TYPES OF NATURAL CAPITAL

Sustainable management of natural assets increases the load-bearing capacity of the environment, thereby contributing in the long run to sustainable growth in production. However, natural assets are different, and thus we should differentiate the individual categories (Chart 2-1).

Chart 2-1: Classification of the natural capital by management



Source: World Bank (2012), MNB.

Exhaustible, but renewable energy sources (fishing, natural forests, soil and water) are usually collective property, i.e. nobody can be excluded from the consumption of the natural assets and the consumption of such influences the consumption of others. Accordingly, **consumption of the resource exceeds the optimal level** (tragedy of the commons), and thus sufficient time is not left for renewal of the natural assets, which ultimately may lead to exhaustion of the resource.

Due to the rising global population, food consumption is expected to increase. Consequently, the role of agricultural renewable energy sources (cultivated plants, farmed animals, aquaculture, forest plantations) is expected to increase in the future, and thus it is essential to manage them.

Non-renewable energy sources (oil, gas, coal and minerals) may also represent an ecological constraint. Since the Meadows report in the 1970s, a report prepared for the Club of Rome, economic models have been examining whether – considering natural assets as limited factors of production – it is feasible to achieve sustainable growth. As a result of technological progress, **it has become possible to replace non-renewable natural assets with renewable resources; the only question is when the time of technological transition will occur (Solow (1974), Stiglitz (1974)).** Compared to these analyses, **Stokey (1998) and Lieb (2001)** present an extremely pessimistic vision, as according to them the output of the economy decreases in parallel with the exhaustion of resources and innovation cannot offset this in the long run. By contrast, according to **Smulders (1994), Bovenberg and Smulders (1995, 1996)**, if the exhaustion rate of the future green innovation and resources is sufficiently low, a strict environmental policy will ensure sustainable development, considering the environment, in the long run. **While at the time of the Meadows report, science took the position that the limits of the environment are primarily determined by the finiteness of energy resources**, nowadays – despite the increasing population and uninterrupted development of the global economy – the issue of the scarcity of resources has been pushed to the background. **In the case of certain resources which were previously considered to be finite, such as oil and natural gas, the volume of exploration is able to keep pace with the increasing consumption as a result of technological innovation** (Kaderják et al., 2011). At the same time, the load-bearing capacity of nature in the area of other natural assets, such as e.g. rare earth metals, the biosphere or drinking water, appears to be limited.

The aforementioned natural assets contribute directly to meeting mankind's needs (food, water, energy, etc.). In addition, there are **non-provisioning services**, which appear indirectly. These essentially **fulfil regulatory and support tasks but may also contribute to cultural services**. This includes catchment areas, climate regulation services and nature tourism. In relation to non-provisioning services, the basic task is to understand the real value of these services as thoroughly as possible. Accordingly, those should be also taken into consideration when making real political decisions, and efforts should be made to preserve and restore them.

Impact of the degradation of environmental factors on other factors of production

As a factor of production, natural capital is able to generate bottlenecks in production in an indirect manner as well. **Environmental degradation can reduce the volume and qualitative attributes of other factors of production (capital, labour, efficiency) via several indirect channels.** We examine these one by one, illustrating the phenomenon through a variety of examples.

Degradation of the natural environment significantly restricts physical capital as well. **The increasing frequency of extreme weather conditions** (hurricanes, floods, forest fires, etc.) **as a result of the climate change materially reduces both the volume and quality of the capital stock.**

In the future, natural disasters may occur in increasingly higher numbers, destroying residential buildings, factories, public institutions and the machinery and assets used there. Accordingly, precautionary measures should be taken primarily in areas which are more susceptible to such disasters.

With extreme weather conditions becoming more frequent, we see more and more examples of damage to physical capital all over the world, and climate change also increases the future risks. **Hurricane Sandy caused havoc in New York in 2012**, but according to the forecasts by 2050 37 percent of Lower Manhattan will be exposed to floods. Accordingly, the city's management plans to spend several billion dollars on the protection of the city, including building mobile barriers and enclosing State Island with a 5-km sea wall.

Floods are becoming increasingly more frequent in several coastal cities with increasing populations in Asia, **including Jakarta.** Moreover, due to the concentration of the global demographic boom in Asia, **according to the Asian Development Bank, the population may double between 2000 and 2060 in the areas hit by floods.** The situation is further exacerbated by the fact that larger areas are concreted and asphalted, which also reduces natural absorption capacity. In addition, the coastal area of Jakarta is sinking 25 cm every year, while the sea level is rising by 0.8 cm. In response to this, the Indonesian government recently announced that it would move the capital to a new location further from the ocean, which is thus less vulnerable to natural factors.

Among the ecological constraints, the impact of the current status of the environment on labour is also an important factor. **Poor environmental factors deteriorate employees' workload capacity and health condition, as a result of which they can work less** and their efficiency may also deteriorate. The analysis by WEF highlights the fact that at present one **of the most significant health risks is air pollution,** which affects more than 90 percent of the global population. Poor air quality has major economic effects, the total cost of which can be measured in billions of dollars (WEF 2019). As a result of the aforementioned factors, **the number of illnesses increases significantly (including coughs and sore throats, while in more serious cases it may lead to lung cancer and heart disease)**, which results in decreasing labour force productivity. **According to the WEF forecast, poor air quality may worsen to such a degree by 2060 that it may cause 3.8 billion days of sick leave at the annual level.** By mitigating climate change, the resulting losses may be reduced, which may lead to an increase in production.

Numerous studies surveying the environment's effect on the labour force are available. In March 1991, Carlos Salinas – then president of Mexico – ordered the immediate shutdown of the giant oil refinery, Azcapotzalco – operating in the Mexico City area – to reduce the air pollution afflicting the capital. The number of respiratory infections, nose bleeds and pulmonary emphysema peaked in the winter preceding the closedown. The refinery, which accounted for 35 percent of the country's capacity, emitted 85,000 thousand tonnes of air polluting substances annually, mostly sulphur dioxide. This accounted for 2 percent of the total volume emitted in the capital and its surrounding areas. Based on the data for the respective period, Hanna and Olive (2011) examined how sulphur dioxide in the air impacts labour supply. The co-authors found that **1 percent rise in sulphur dioxide resulted in a decrease of 0.4-0.7 percent in the working hours of the following week.**

In North-West India, 39 million tonnes of rice straw is burnt for next year's sowing work in order to clear the croplands. This burning process is one of the most important sources of air pollution affecting Delhi and most of the large cities in India – 9 of the 10 cities with the worst air quality in the world are located in India. **Based on the calculations performed by the International Food Policy Research**

Institute (IFPRI), the pollution generates an annual cost increment of USD 30 billion for India. Ikea's latest collection is meant to address this problem. Instead of burning it, farmers can take rice straw to collection points, which then continues as base material for Ikea furniture, as a result of which the degree of air pollution will improve on the whole.

Degradation of the environment and climate change have negative effect on global productivity via several channels. The issue has not been included in the key research areas of economists for a long time; however, **the increasingly more frequent occurrence of extreme hot days and extreme rainy/rainless period seen recently has shifted the focus of analyses to this problem**. Based on a conservative estimation by the ILO (2019), the **rise in heat stress** (a high ambient temperature that is difficult for the body to tolerate; usually a temperature over 35 degrees Celsius with high humidity) **will reduce global working hours by 2.2 percent by 2030, equivalent to the termination of 80 million jobs or the loss of USD 2,400 billion.**

Naturally, **agriculture is the sector most exposed** to extreme weather conditions. Significant fluctuations in the quantity and changes in the pattern of precipitation, as well as the major increase in temperature significantly reduce crop yields. According to Deryugian and Hsiang (2014), the aforementioned factors **in the USA reduced farmers' daily income by USD 3 on average between 1969 and 2011.** Moreover, according to their forecast, in the absence of proper adjustment, **this value will increase further in the future.** Wheat, rice, maize and soy account for two thirds of human calorie intake, but **the warmer average temperature may reduce crop yields.** If the global average temperature rises by 1 degree Celsius, the average crop of wheat will decrease by 6 percent, while that of rice, maize and soy by 3.2 percent, 7.4 percent and 3.1 percent, respectively.[5] In the event of a higher temperature increase, crop yields will decline to an even larger degree, thereby jeopardising the supply of the increasing population with food.

Graff Zivin and Neidell (2012) examined the productivity of agricultural workers working on a farm in the Central Valley in California. Measurement of the performance and the wage setting of the workers are performed by an electronic system; the system monitors their work by real time data and the wage is settled on the basis of this. The authors compared these data with the ozone concentration of the lower part of the atmosphere.[6] They found that **a 10 ppb[7] decrease in ozone concentration entailed a 4.2 percent increase in the productivity of agricultural workers**.

In addition, higher temperature naturally also **materially curbs energy efficiency,** since protection against the extreme weather conditions consumes major resources. Just think about the penetration of the air conditioning equipment in the past decades.

2.2 What can we expect if nothing changes?

The 2011 report[8] of the UN's Environmental Programme on the green economy examines the changes in economic, social and environmental variables with the realisation of different assumptions. **The report's baseline scenario projects a continuation of the present trends, i.e. high energy consumption and greenhouse gas emissions, and the exhaustion of environmental resources.** According to the assumptions, **no technological change takes place**, i.e. utilisation of the currently available, polluting technologies remains typical. In this scenario, population growth continues, and the number of employees also rises, reaching 4.8 billion persons by 2050. Real GDP may be roughly USD 151.3 trillion,[9] while the GDP per capita may rise to USD 17,000 by 2050. As a result of economic growth, the number of those living below the poverty line declines further. Value added rises, albeit to a different degree, in all three sectors (agriculture, industry, services). However, the growth path presented has a price, as environmental degradation continues to accelerate, and the production constraints of the economy ultimately become effective, leading to a sharp decline in the long run.

Population and GDP growth result in a further rise in global energy demand (19,733, Mtoe, million tonnes of oil equivalent), a large part of which (81 percent) is still provided by fossil fuels. In line with higher population and GDP, by 2050 total water consumption increases by more than 70 percent compared to its 2011 level, which entails further acidification of waters. In line with increasing demand for food, areas of agricultural cultivation – croplands and grasslands – increases, and partly due to this, the ratio of forest areas decreases further (3.7 billion hectares in 2050), resulting in reduced carbon capture. **Larger population and higher income also entails an increase in waste production.**

5 Zhao et al. (2017) https://www.pnas.org/content/114/35/9326
6 Ozone is one of the components of smog, and apart from this it is a health hazard substance on its own as well.
7 Part per billion gas particle.
8 UNEP (2019).
9 Fixed USD 2010.

As a result of the processes presented above, the **world's CO_2 emissions steadily rise and by 2050 they exceed the level from 2009 by 81 percent.** At this emission level, the **atmospheric concentration of greenhouse gases will be around 1,000 parts per million (ppm) in 2100,** which is consistent with an increase in **global average temperature of roughly 4 degrees Celsius** compared to pre-industrial levels. **The ecological footprint rises further, and in 2050 maintaining human activity will require twice as much resources as the Earth is able to provide in one year.**

This scenario is accompanied by numerous negative impacts in respect of water supply, food production, human health, availability of lands, and ecosystems. By 2050 water shortage, the rise in sea levels, the strengthening of storms, soil erosion and saltwater intrusion will affect several hundred million of people. 15-40 percent of a myriad of living creatures and species of animals are already threatened by extinction with warming of 2 degrees Celsius. The fall in crop yields will jeopardise the ability to feed hundreds of millions of people, particularly in Africa.

Based on the mainstream literature on the topic, with an **average temperature** that exceeds the pre-industrial levels **by 4 degrees Celsius or more,** the picture of the planet may change radically, which is summarised by Stern (2013):

- **Desertification** may affect a large part of South Europe and Mexico, and the area of the Sahara may grow, potentially resulting population migration.

- The **snow and ice** covering the Himalaya **may melt,** resulting in large-scale flooding and soil erosion.

- The melting of the snow and ice in the Andes and the Rocky Mountains may dramatically change the water supply of the western regions of South and North America, and the Amazon. Precipitation may fall in the form of rain rather than snow, which may lead to floods, and **jeopardise the access of several billions of people to water.** Moreover, due to this, significant impacts on agriculture may also be rendered probable.

- The **monsoon of north India may change radically,** influencing the lives of hundreds of millions.

- The **Amazon rainforest may die out**, as a result of which a large volume of carbon dioxide will be released into the atmosphere.

- The **extreme weather conditions**, such as cyclones, may become even more intensive.

- **Windstorms** may lead to the salinification of large areas, becoming unsuitable for agricultural cultivation.

- **Global sea level may significantly rise**, especially if land ice melts into the ocean.

As a result of their geographical location, **developing countries are exposed to warming to the largest degree**, and they also have less resources for the – social, technological and financial – management of climate change. These events may trigger substantial population migration, leading to severe conflicts.

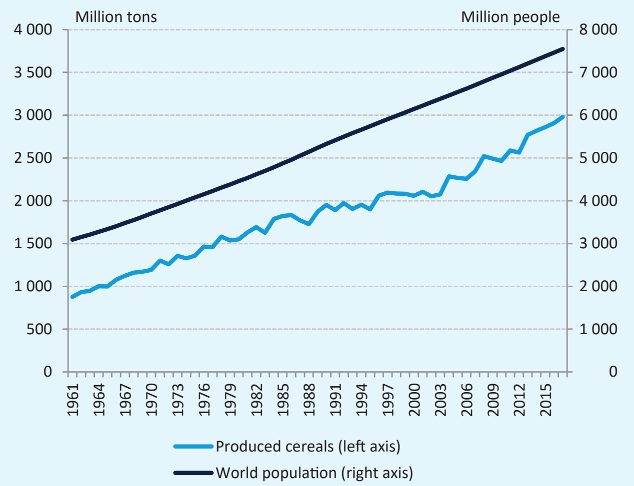
Science and the models forecasting the impacts of climate change are continuously developing, **but the new results paint an even more worrying picture than before.** In the worst case scenario included in the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC), by the end of the century average temperature may rise by 5 degrees Celsius compared to the level registered before the industrial revolutions. However, according to the new climate models of two leading French research centres – which will replace the models currently used for the UN projections – **by 2100 average temperature may be higher by 7 degrees Celsius than the pre-industrial level, if CO_2 emissions are not reduced.** One of the most important results of the new models is that the **increased atmospheric CO_2 concentration will heat the surface of Earth faster than assumed based on previous calculations.**[10]

The world's population rose to an unprecedented degree during the 20th century, from 1.7 billion to 6.1 billion persons, i.e. the number of inhabitants on Earth increased almost fourfold. **On the whole, in the past decades, food production was able to keep up with the fast increase in population.** Between 1961 and 2017, global population rose almost 2.5-fold, while the volume of grain grown rose more than threefold (Chart 2-22). The substantial rise in the volume of grain grown was mostly facilitated by the increase in productivity (e.g. irrigation, use of pesticides and fertilisers), and it was attributable only to a minor degree to the increase in cultivated areas (OECD and FAO, 2019). However, looking ahead, natural resources may represent an increasingly more effective constraint in terms of the unsustainable population growth in the developing countries.

10 AFP (2019)

In the coming decades, global food supply trends may face a number of challenges: *due to the unsustainable demographic policy of developing countries* – providing food for the rising size of global population in adequate volume and quality, reducing the number of those starving, while the environmental considerations also come into focus to an increasing degree (Chart 2-2). Agricultural production may face constraints due to the scarcity of natural resources used for production and also due to the unfavourable effect of climate change on crop yields (FAO, 2019).

Chart 2-2: Volume of corn grown and changes in global population, 1961–2017



Source: FAO, UN.

In the future, demand for food may rise substantially due to three factors: growth in the global population, rise in incomes per capita and change in the composition of the consumer basket (FAO, 2018). In parallel with the increase in income per capita, the weight of food increases at the beginning of the period, then – as the income continues to grow further – it starts to decrease. The increase in incomes also alters the consumer basket; within the food consumption preferences the ratio of food rich in protein (meat, milk, eggs) rises (FAO, 2018). However, the production of food of animal origin requires larger volume of natural resources and creates a larger ecological footprint.

The quality and scarcity of the available resources (soil and water) may restrict food production from the supply side. Agricultural production more than tripled between 1960 and 2015 (OECD and FAO, 2019), which also increased environmental burdens through deforestation and through that the chemicals used in the cultivation of land leach into the soil. Agriculture is one of the largest users of water reserves: 70 percent of the available water is used by the agricultural sector (FAO, 2018).

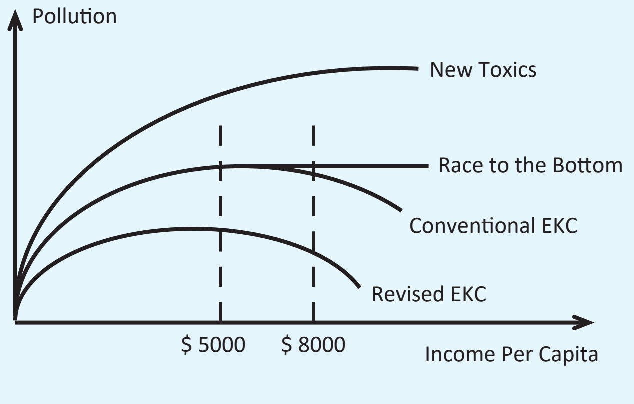
Based on current estimates, we are in the 24th hour, and thus the prevention of a climate catastrophe calls for intervention as soon as possible.

2.3 Techno-optimism – The environmental Kuznets curve

The relation between pollution and **economic development was first examined by Grossman and Krueger (1991)** through the countries' sulphur dioxide and solid particles (smoke) emission. **According to their assumption, there is an inverted-U relationship between income per capita and pollution**, which they characterised as the **Environmental Kuznets Curve** (EKC). The shape of EKC is formed by the combined effect of three factors. **Pollution increases in proportion to growth in production**, which explains the ascending section of the curve. **After a certain development level, emissions of pollutants peak.** Structural transformation of the economies and the **progress in the services sector cause the curve to reverse, and besides this, the process is also supported by technological progress and investments aimed at cleaner production.** According to this analysis, environmental pollution and the degradation of environmental assets decrease significantly in parallel with development, i.e. the process is capable of setting itself on a sustainable path.

Dasgupta et al. (2002) examine the shape of EKC from an economic policy perspective, and they find that **as a result of the globalisation**, in the competition, production – and the location of the industrial, polluting factories – adjust to the prevailing minimum standards, as a result of which the returning tail of the curve disappears. At the same time, they question the role of developing countries in terms of their impact on the development of the aggregated curve, since upon applying the available green technologies they may cut their pollutant emissions, as a result of which the environmental Kuznets curve may shift to the left and downwards (Chart 2-3). However, this necessitates the global coordination of environmental policies and the sharing of technologies.

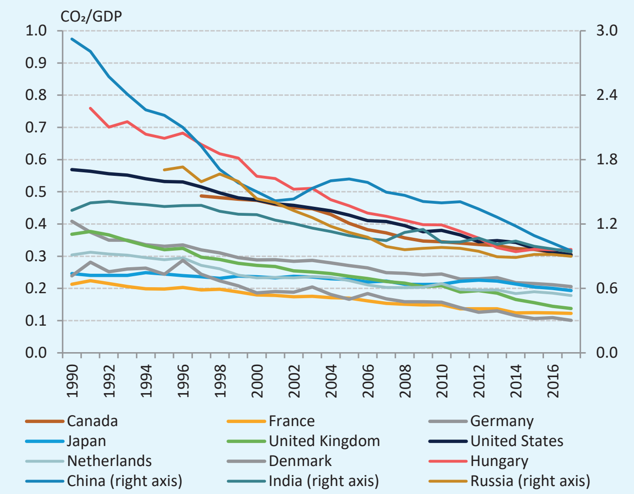
Chart 2-3: Environmental Kuznets curve and its criticism



Source: Dasgupta et al (2002), p. 148.

Based on the latest available data, the more developed the countries are, the more energy efficient production they have. This is due to two reasons: on the one hand, as a result of structural transformation, the economic output of more developed countries is more service-intensive, while the role of traditional industrial production declines as a result of outsourcing. On the other hand, on the path of economic development typically less and less harmful and cleaner innovations may be implemented to an increasing degree (Chart 2-4).

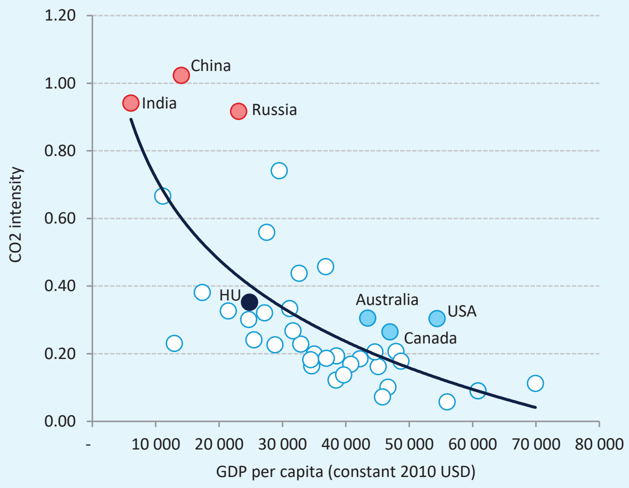
Chart 2-4: Energy intensity since 1990 in individual countries



Source: Own compilation based on OECD.

In line with this, the cross-sectional data of the OECD countries and some large developing countries (China, India, Russia, Indonesia, Columbia) show negative correlation between GDP per capita and the economy's carbon dioxide intensity. Hungary has a slightly lower CO_2 intensity compared to its economic development (Chart 2-5).

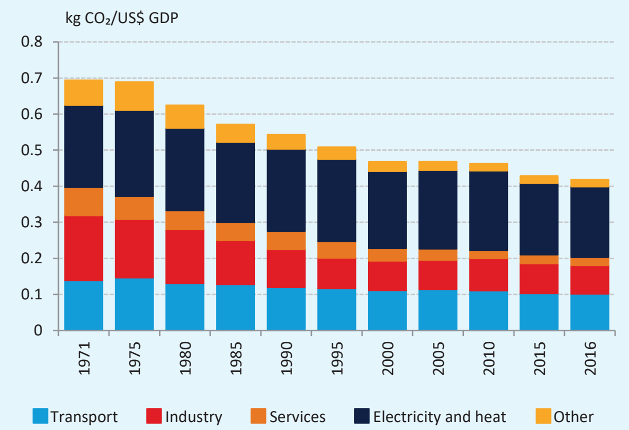
Chart 2-5: Relationship between energy intensity and economic development in 2017



Source: Own compilation based on OECD.

Examining energy intensity at the industry level, we found that the value as a percentage of GDP decreased substantially, which was mostly attributable to industrial production with high CO_2 emissions (Chart 2-6). However, the intensity of the energy and transportation sector – responsible for almost 70 percent of the aggregate emission – has not changed much in the last 50 years.

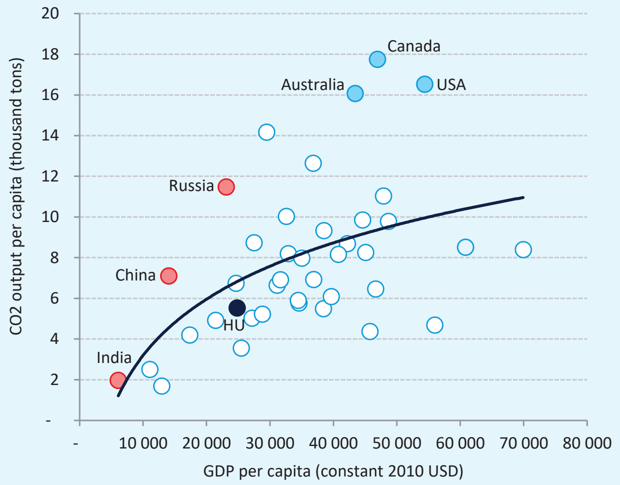
Chart 2-6: SCO₂ emission by sector as a percentage of GDP, 1971–2016



Source: IEA, MNB calculation.

However, despite decreasing energy intensity, the tail of the Kuznets curve does not reverse in the way assumed by the theory, and thus the present form of economic growth is not environmentally sustainable (Chart 2-7). The primary reason for this is that countries fail to spend enough on reducing pollution. Until 1975, in the United States the costs spent on this rose from 1.3 percent of GDP to around 1.7 percent, while between 1975 and 1995 they remained relatively steady, around 1.6-1.8 percent of GDP.

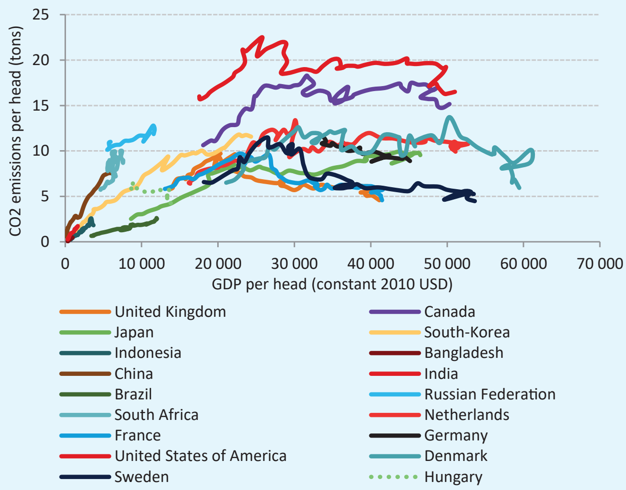
Chart 2-7: Relationship between CO2 emissions per capita and economic development in 2017



Source: Own compilation based on OECD.

In the case of the Asian countries that have undergone radical development in the past 50 years (Japan, South Korea), it can be clearly seen that following the steep increase in pollution in the early phase of the development, the Kuznets curve flattens out in the more developed stage. The pollution emissions of certain developed countries stabilised at a high level, or in certain cases their pollution reversed slightly in parallel with development, which was also supported by the Kyoto Protocol. Hungary belongs to this latter group as well. On the other hand, at present the countries of the developing world are still on the ascending section of the curve (Chart 2-8).

Chart 2-8: Environmental Kuznets curve per capita in individual countries



Source: Own compilation based on World Bank.

Thus, globally it is not obvious that pollution emissions clearly decrease as a result of economic development. **If we want to maintain high growth rate globally, then much larger financial, scientific and regulatory resources must be appropriated for the reduction of pollution compared to the past. Accordingly, the realisation of a new, green industrial revolution is essential, which results in the rise of green technologies and more energy efficient production.**

2.4 The green growth scenario

Based on the literature and available estimates, the current economic growth path observed globally is not sustainable ecologically, since it takes place in conjunction with the drastic degradation of nature.

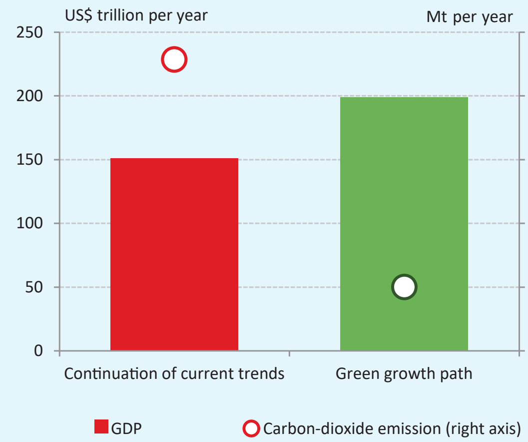
The spread of green innovations makes the realisation of a sustainable, green growth scenario achievable in the world, which does not necessitate curbing economic growth. The new growth scenario ensures the improvement and recovery of natural assets, which also has direct, favourable impact on other production factors (capital, labour, technology and efficiency).

Based on the projections related to the green growth scenario, according to the UN's calculations,[11] 2 percent of global GDP should be used annually on investments that improve energy efficiency and reduce carbon intensity, and at the same time contribute to job creation and supporting growth. **In the short and medium term, growth is lower than in the scenario assuming the continuation of the present trends, but in the long run the green scenario results in higher welfare and sustainable growth.**

In the green growth scenario, in 2050 real GDP may be around USD 200 trillion, which corresponds to an annual average growth rate of 4 percent. In parallel with this, productivity may increase by roughly 2 percent in annual terms, and thus at the end of the horizon (2050) it may exceed USD 40,000 globally. At the same time, due to the development of green industries, the CO_2 emissions of the economy may decline from the present level of almost 37 billion tonnes to 20 billion tonnes (Chart 2-9).

11 UNEP (2019).

Chart 2-9: Real GDP and CO2 emissions in the case of continuation of the present trends and in the green growth scenario in 2050



Source: UNEP (2011).

In **agriculture, green investments** primarily focus on research and development, plant protection and food processing. Owing to more efficient plant protection and to the artificial amelioration of soil quality which both develop as a result of investments, **crop yields per hectare are higher.** Developments are important particularly in those countries where agriculture makes the largest contribution to growth. In most of the less developed countries, **making agricultural production sustainable** may not only result in higher performance and larger crop yields, but also improve nutrition and **foster food safety.**

In the green growth scenario, forest areas may increase to 4.5 billion hectares, as a result of reducing deforestation and increasing afforestation. Thus, according to the UNEP calculations, 502 billion tonnes of carbon may remain in the forest ecosystems in 2050, which exceeds the 2011 value by 21 billion tonnes. Afforestation takes a longer time, and thus in this area investments do not yield instant spectacular results. However, **in the long run the growth in forest areas may improve soil quality and contribute to the improvement of access to water**, which has a positive effect on agricultural production.

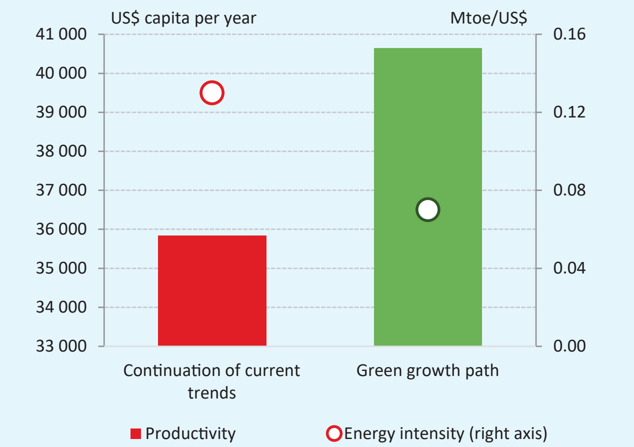
In the fishing sector, investments are allocated to three key areas, namely to the prevention of overfishing, the upskilling of fishery workers and support for the recovery of fish stocks. In the short run, for the recovery of the depleting fish stocks, the fishing capacity must be reduced. At the same time, **investments contribute to the creation of sustainable fish farming in the long run.**

Although higher income would result in higher demand for energy and water, **green investments facilitate the protection of resources by increasing energy efficiency and the transition to renewable energy resources.** On the supply side, investments in the energy sector contribute to the production of bio fuels, energy production from renewable resources and technological progress (Chart 2-10).

In the green growth scenario, an increasing portion of energy consumption is covered by renewable energy resources. On the demand side, the focus of green investments is on increasing energy efficiency, particularly in the area of manufacturing and transportation. Energy saving efforts result in lower primary energy demand compared to the scenario assuming continuation of the present trends. **In the green growth scenario, demand for fossil fuels decreases** due to the development of the public transport networks, increasing energy efficiency and the rising use of renewable energy resources.

According to the green scenario, roughly USD 650 billion should be spent globally each year solely on investments that foster energy efficiency and reduce CO_2 intensity. In addition, further investments are necessary also in the other key sectors, and **both the government and the private sector should contribute their share to this.** Similar recommendations are made by the World Bank's current projection to invest USD 89 trillion in infrastructure over the next decades to achieve the climate target set by the Paris Climate Convention. **Based on the simulations, on the whole, in order to realise the green growth scenario, investments in green technologies should amount to minimum 2 percent of global GDP.** Moreover, based on the analyses, the developing economies should spend more than average, while the spending of the developed economies should be below the average; in addition, the distribution between industries should also move proportionately with the sectors' pollution emissions. The efficiency-increasing effects of the investments appear both in direct and indirect form. Directly, infrastructure investments efficient in terms of energy consumption and the adaptation of resource preservation technologies could serve as a solution, while through indirect channels research and development investments aimed at the conservation of natural resources could be progressive. According to the calculations, on the whole the annual growth rate of investments should be around 5 percent; on the other hand, all analyses emphasise that the return on green investments (ROI) can be demonstrated over a much longer run, and thus economic policymakers must take this into consideration in making their decisions. By contrast, as the available data show, **in 2018 the amount spent on enhancing energy efficiency only amounted to USD 240 billion (IEA, 2019)**, which roughly corresponds to the 2017 value. The stagnation is primarily the result of the decrease in investment related to energy-efficient buildings. Thus, on the whole, global commitments fell short of the desired levels (compared to the 2 percent green investment ratio, countries spent only 0.7 percent globally), with the welcome exception of the Republic of South Korea and China**,** which at the same time also serve as an example for the other economies. The aforementioned countries spend almost 5 percent of their GDP on the development of green industries and have a long-term vision.

Chart 2-10: Productivity and energy intensity with continuation of the present trends and in the green growth scenario in 2050



Note: Productivity data are in US dollar of 2010, while energy intensity data are in USD billions. Mtoe: Million Tonnes of Oil Equivalent
Source: UNEP (2011).

Due to the finiteness of natural assets, raising crop yields may serve as a solution to meet the increasing demand for food. At the same time, crop yields between 1990 and 2018 were only able to rise at a rate of 1 percent, which – based on the projections – will not be sufficient to satisfy the mounting needs without an extensive increase in cropland area or deviation from the current consumption trends. According to the report of the Food and Agriculture Organisation, **taking the present trends as a basis, a crop yield increase of 2.5 percent** would be necessary until 2050 (FAO, 2018). According to the forecast of the Food and Agriculture Organisation, agricultural output may increase by 32 percent until 2030 and by 50 percent in total until 2050 compared to the present one (FAO, 2018).

The average productivity of the 12 highest ranked countries, based on crop yields, exceeds the productivity of the countries of the lowest crop tenfold, which provides substantial room for achieving crop surplus based on production efficiency (McKinsey, 2015). Efficient agricultural policies may facilitate production aligned with food requirements. For example, in China, rice, wheat, soy bean, bread, vegetable oil and meat reserves were accumulated through warehousing, operating in 31 provinces, in order to control supply and market disturbances, as well as contain food price inflation. In the Arab Emirates, which is dependent on food imports, reserves sufficient for 12 weeks were accumulated in similar warehouses, and a trading house was also set up in order to diversify suppliers (McKinsey, 2015). Similar **measures help reduce the losses arising from the spoiling of food along the supplier chains.**

The future rise in demand for food may be partially reduced by decreasing food waste. Based on data from the Food and Agriculture Organisation, one third of the food produced, i.e. globally 1.3 billion tonnes of food annually, is not consumed (FAO, 2011). While in the medium- and high-income countries it is typically in the consumer phase when the food is not consumed, in the low-income countries food is wasted in the early and medium stage of the food chain (FAO, 2011). **In Europe and North America, 95-115 kilogrammes of food is thrown out annually and per person**, while in Sub-Saharan Africa the volume of unconsumed food is around 6-11 kilogrammes annually. **Unconsumed food also represents a waste of natural resources,** since the land, water and energy used for the production was consumed in vain (FAO, 2011).

In the field of water management, the focus is also on efficiency, and the preservation of surface and ground waters also receives special attention. Green investments in the sector increase access to drinking water and water supply, the efficiency of water consumption and water reserves through salt extraction. Demand for water is lower than in the scenario anticipating continuation of the current trends owing to the efficiency increase implemented in agriculture and to the industrial investments. Sustainable water management and larger water reserves facilitate the preservation of surface and ground waters. Investments in the sector have particularly important effects in the developing countries, where developments may contribute to the increase in agricultural crop yields and thereby indirectly also to the reduction of poverty. At the same time, water shortages increase even in the green growth scenario and more than 60 percent of the population may be affected by water-related problems in 2050.

In the field of waste treatment, green investments result in more efficient waste collection, recycling and composting. Recycling contributes to the reduction of energy demand, pollution emission and production costs.

For the quantification of the effects of climate change we applied “reverse logic” (Table 2-1). **We defined the degree**

of global warming as a target variable. Based on this, we defined 2 degrees Celsius, achievable in the green scenario set by the UN, as the ultimate result to be realised.[12] According to our calculations – which are based on the UNEP report – in order to achieve the desired target, **CO_2 emissions must be drastically reduced by 2050.** In the green growth scenario, CO_2 emissions may be around 20 billion tonnes per year compared to the present 37 billion tonnes (i.e. on an annual average emissions decrease by 0.4-0.5 billion tonnes). Thus, the atmospheric CO_2 concentration rises further from 410 parts per million in 2018 to 500-600 parts per million, but the rate of increase may be substantially slower than observed in previous periods.

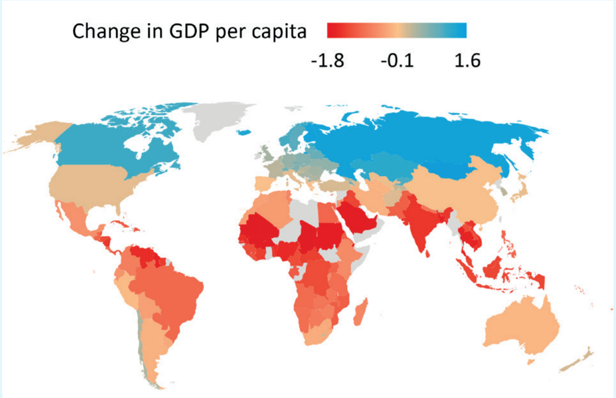
Based on the analysis of the New Climate Institute and the Climate Analytics (2019), **national climate protection measures are not sufficient to prevent global warming from exceeding 2 degrees Celsius** by the end of the century.[13] If the present commitments of the countries are fulfilled, the global average temperature may be 2.9 degrees Celsius warmer by 2100. Today, most countries fail to fulfil the necessary commitments, but there are also some positive trends. In a number of developed economies – particularly where emissions regulations were introduced – the volume of CO_2 emissions has fallen substantially (Le Quéré et al., 2018). In addition, the changeover to renewable energy resources and the decrease in energy consumption, achievable by boosting energy efficiency, also contributed to the reduction of emissions.

Owing to the innovations of the green industrial revolution, global GDP increases, but due to the smaller increase in employment, **productivity substantially rises.** Increase in productivity and sustainable growth, as a basic condition, imply that the **average working hours of employees decrease, as a result of which their free time increases.**

In the green growth scenario, the ecological footprint will decline to 1.2 Earths in 2050 from the present level of 1.7. Thus, although the ecological needs of mankind still exceed the Earth's load-bearing capacity, substantial improvement can be achieved by taking the right steps.

The regional distribution of the disadvantages stemming from climate change is not even among the regions of world. **If the global average temperature exceeds its pre-industrial level by 2 degrees Celsius**, GDP per capita in the countries located in the northern hemisphere may increase, since the warmer climate facilitates the introduction or expansion of agricultural activities for which the respective area was previously unsuitable due to the colder climate. At the same time, in most developing countries GDP per capita decreases (Chart 2-11), due to unbearable change in climate.

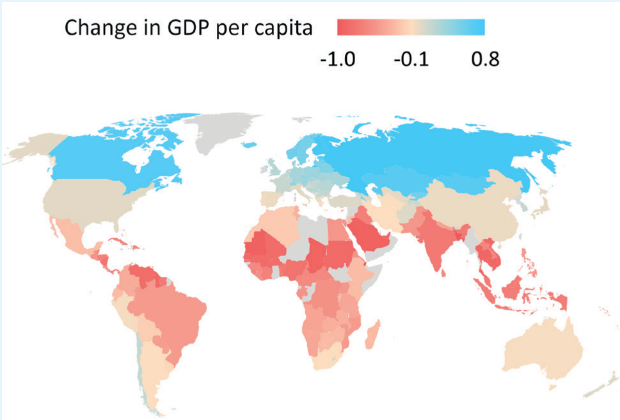
Chart 2-11: Change in GDP per capita with a global average temperature increase of 2 degrees Celsius



Note: For the countries marked with grey no data are available.
Source: MNB compilation based on Pretis et al. (2018).

Based on the current situation, in the absence of fast and drastic measures there is little chance of keeping warming below 1.5 degrees Celsius; however, in this case the welfare loss would also be more moderate compared to a temperature increase of 2 degrees Celsius (Chart 2-12).

Chart 2-12: Change in GDP per capita with a global average temperature increase of 1.5 degrees Celsius



Note: For the countries marked with grey no data are available.
Source: MNB compilation based on Pretis et al. (2018).

12 It should be emphasised that the latest estimates designate the temperature increase of 2 degrees Celsius as a target the attainment of which is increasingly more difficult.

13 https://climateactiontracker.org/documents/644/CAT_2019-09-19_BriefingUNSG_WarmingProjectionsGlobalUpdate_Sept2019.pdf

Table 2-1: Forecasts for 2050 with realisation of the assumptions in the scenarios

	Degree of global warming	CO_2 emissions (billion tonnes/ year)	Energy intensity (million tonnes oil equivalent/ USD billions)	GDP (USD billons/ year)	Productivity (GDP/ employee, USD)	Employment (billion persons)
Continuation of current trends	~ 2.7 – 4.5 °C	55.7	0.13	172,049	35,844	4.8
Green growth scenario	~ 2 °C	20	0.07	199,141	40,641	4.9

Note: Data are presented in USD of 2010.
Source: MNB calculation based on UNEP (2011) and IPCC (2019).

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3 Economic theory and political recommendations for environmental sustainability

Climate change can now be regarded as the greatest market failure in the world, which results in negative externalities, information asymmetry, inconsistency in time, the tragedy of the commons and failure stemming from network effects. Climate change causing market failure supports the position that the government must play a role in environmental protection, while the relation between climate protection and economic growth is not clear.

The results of economic approaches and impact assessments analysing the effects of climate change vary on a wide scale, and give entirely different answers with regard to the need for climate policy. While according to the results of the classic Nordhaus economics, growth can be maintained even without an active climate policy, and moderate carbon reduction can solve the problems, the school applying the Stern approach – nowadays regarded as consensus-based – perceives the economic damages as being enormous and proposes a new green industrial revolution to support green growth. Green growth policy emphasises the need for a global solution to emissions restrictions. The latest and most radical response to climate change is given by the macro ecological degrowth theories, according to which sustainability can only be achieved with a significant moderation in economic output, which also involves changing consumer habits and reducing market competition.

A state with a targeted mission may successfully appear in the sub-markets of high market risk and high capital intensity, focusing on environmental sustainability, thereby diverting the market toward the subsequent, sustainable green development scenario it deems desirable. Transition to the green growth scenario may be fostered by directed technological change, both in economic policy and at business enterprises. Directed technological change is a series of complex economic policy steps that include the diversion of the factors of production (capital and labour) and innovation towards the green economy. In the aforementioned model, the role of the government is to adjust market failures, hinder – via tax policy – innovations resulting in higher greenhouse gas emissions and foster the development of green industries by elaborating a complex subsidy scheme. The empirical results of directed technological development show that from the corporate side, taxes have a positive effect on the suppression of harmful technologies and subsidies on the spread of pure innovations. Regulatory measures targeting the general public are generally high in societal costs and do not focus well enough on the target groups. If the regulator does not know enough about the population's price elasticity and willingness to consume, the programme can easily become ineffective.

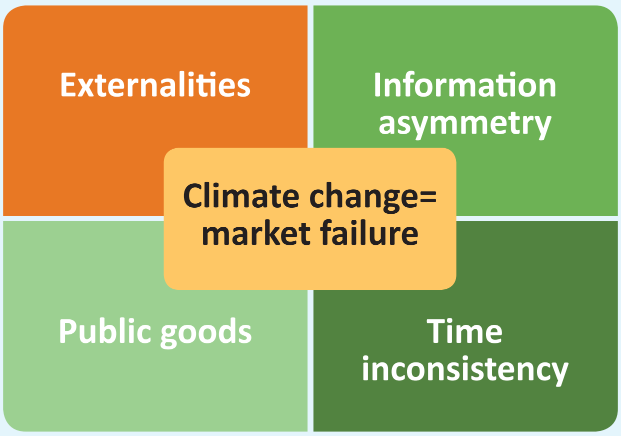
3.1 Climate change as the greatest market failure

Climate change can now be regarded as the world's greatest market failure (Chart 3-1). Economic production and the satisfaction of consumer needs have numerous harmful side effects, due to which the desired social optimum is not achieved.

Emissions of greenhouse gases are a harmful by-product of human activities, i.e. an externality. The external cost of eliminating emissions does not burden the companies and households performing the activity, since in accordance with the market failure theory the private incentives for the mitigation of environmental damages are smaller than the interest of the whole society would be. Accordingly, it may only be ethical rather than economic logic that may force the profit-maximising business sector or consumers maximising their own welfare to reduce their emissions.

The uncertainty of the models describing climate change and the century long horizon result in major information asymmetry among the members of the society. The key political and economic agents, interest groups supporting fossil fuels and a number of other external agents question – taking advantage of the uncertainties inherent in climate change models – the dangers caused by climate change, and dispute the implementation of laws necessary to address it and the strength of those laws.

Chart 3-1: Components of the market failure of climate change



Source: own compilation.

Mitigating climate change could be facilitated by several, already available, technological innovations; however, the absence of the critical mass necessary for the penetration of those innovations results in failures connected to network impacts. Installation of the new type of smart metering networks, the penetration of household solar cells, the digitalisation of public utilities, the network of e-car charging stations, or the expansion of community car sharing would clearly contribute to lowering consumers' hydrocarbon consumption. However, the penetration of network industries and products is conditional on the existence of a critical mass; without this, it is difficult to develop networks and it would be uneconomical to operate them. Due to this, it is essential to enhance the environmental awareness of the society (see Chapter 4 for details).

The existence of market failures is one of the most important explanations for the need for economic intervention by the state. **The externalities of the activities causing climate change, the information asymmetry and the network failures all call for the government to play a role in environmental protection.** The primary method of managing externalities is to internalise the costs of pollution emissions, which, for example in the case of CO_2 emissions, would mean that **of the global cost of carbon, all pay tax, at a specific unit price, in proportion to the volume they emit.** However, the state may not only impose taxes, but also determine emission quotas and regulate the trading thereof. As a result of this, consumers could move toward less polluting consumption accompanied by less harmful by-products, while companies would follow cleaner production trends. **Accordingly, public policy interventions primarily mean taxation that increases the price of the activities emitting greenhouse gases and divert to clean production and consumption, and in addition stimulate the innovations of low-emission technologies.**

The market failure of the erosion of nature caused by economic activity is also accompanied by innovation failure. Market incentives do not support green innovations of low CO_2 emissions, which do not pollute the environment, since the cost of those is presumably higher than enhancement of the polluting processes moving at the present technological border. **Due to the innovation failure, it is not sufficient to impose a tax on harmful production, but rather it should be accompanied by the support of clean production and green innovation.**

On the other hand, the relation of climate protection and environmental regulation to economic growth is not straightforward. The basic reason for this is that there is no widely accepted result with regard to the magnitude of the effects of climate change. It is questioned how serious the damage to environment is, how much warmer the temperature of the Earth will be in the coming decades under the present economic activity, how warming will impact other parts of the biosphere or at what horizon climate change will exert its impact. **Thus, under the numerous factors of uncertainty, it is also rather difficult to estimate whether the result of environmental regulation will be slower growth or green reforms are able to support positive growth even upon stopping pollution.**

3.2 What kind of climate policy fosters sustainable growth?

3.2.1 THE NORDHAUS APPROACH

Initially, Nordhaus (1975, 1977) also examined the growth effect of innovation and technological progress. He believed that the **exhaustion of resources did not restrain long-term growth, since scarcity enforces more efficient production and the use of alternative, renewable resources.** Having examined the carbon dioxide cycle and the economic effect of limiting emissions, Nordhaus turned to the increasingly more complex presentation of the geophysical relations. Thus, he built a neoclassical Ramsey model extended by geophysical relations, **the DICE model (Dynamic Integrated Climate–Economy; Nordhaus, 1992b) that describes the economic effects of climate change**, supplementing it with material flow and settlement equations. The model equations also include equations capturing the emissions and concentration of pollutants, and the effect of that on climate, as well as those describing the harmful effect of the climate pollution that curbs economic growth. **Nordhaus includes agricultural and health effects, as well as the effects on recreation services in the economic effects.**

The effects, time profile and economic consequences of climate change are most often captured in public policy analysis by *Integrated Assessment Models*, developed on the basis of Nordhaus' DICE model. One of the most important elements of these analyses is estimation of the effects of climate change, one indicator of which is the *social cost of carbon*[14] emitted during consumption or production, returned by the individual estimates.

The growth models integrating the entire social and economic environment determine a pollution emission path, from which the atmospheric concentration of particles is calculated, yielding the future temperature, precipitation and sea level. Based on the damage function derived from the environmental results, the degree of economic damage and the expected growth dynamics can be calculated both at regional and global levels. **The social cost of carbon determines the optimal carbon tax path, based on which environmental policy can encourage the internalisation of the costs of pollutant emissions.** Thus, the government not only manages CO_2 emissions to limit global warming, it also fosters innovations implemented in cleaner technologies.

Based on the theories of the 1990s, although environmental pollution is harmful, the emission of greenhouse gases has no long-term effect on the sustainability of growth. According to the calculations of Nordhaus (1991, 1992a, 2008), although economic growth entails CO_2 emissions, warming of 3 degrees Celsius would only reduce the gross domestic product of the United States by one quarter, or a maximum of 1 percentage point. He estimated the damages related to the global economy, calculated at 2018 prices, to be roughly USD 80 trillion, hardly 1 percent of global GDP, and thus in his opinion **warming only hinders future economic growth in the developed industrial countries to a small degree. Based on the results of the DICE models,** he estimates the present value of the cost of emitting one tonne of carbon hardly at USD 21; thus, he **proposes the introduction of only a moderate carbon tax to resolve the externalities.** In a later analysis, he revises the former results, but still estimates the social cost of carbon only in the amount of USD 31 (Nordhaus, 2017). **Thus, the Nordhaus approach acknowledges the negative impact of climate change (although it does not deem the degree thereof to be major), and he argues for growth that is sustainable even without strong environmental protection.**

However, the optimistic approach has been criticised in recent decades. Among other things, critique has been levelled in relation to underestimation of the importance of the future, underdevelopment of the specification of the damage function, underestimation of the likelihood of catastrophes, and the extent of the damage it causes.

14 The social cost of carbon is the discounted present value of costs caused by one additional tonne of emitted carbon dioxide, which increases in time, since due to the rising level of greenhouse gases in the atmosphere each additional emission generates increasing damages. To illustrate this: the degree of one tonne of emitted carbon dioxide corresponds to the volume of pollutants emitted by a car on the route of roughly 3,500 kilometres between Madrid and Kiev or San Francisco and Chicago.

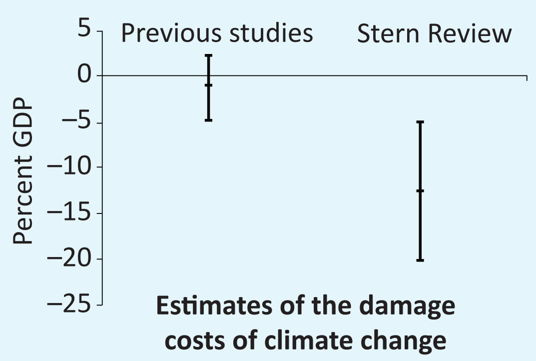
3.2.2 THE GREEN GROWTH SCHOOL

In 2006, HM Treasury (the Ministry of Finance of the United Kingdom) issued the report by Nicholas Stern, assessing the analyses of the previous decades and discussing the impacts of global warming, which – in relation to climate change – outlined a problem that fundamentally differs from the findings of Nordhaus and of the early integrated models (Stern, 2006). **According to the analysis** of the modified PAGE model, applied by the Stern team, **the natural and economic damages may be substantially larger than previously estimated and also irreversible.**

According to their analysis, if the present trends continue, as a result of the general costs and risks of climate change, from now on the level of global GDP will be by at least 5 percent lower annually, while **if the risks and effects of the disasters are taken into consideration more broadly, damages may be as high as 20 percent of global GDP** (Chart 3-2).

According to Stern, emissions of greenhouse gases should be reduced by roughly 3 percent annually to avoid that the global temperature rises by more than 2 degrees Celsius, while **the social cost of carbon may exceed USD 200, i.e. several times higher than the USD 20-30 derived from the DICE models**. Since the benefits of strong and early interventions exceed the expected future costs of delay, **according to the recommendation of the report fast and firm climate policy measures must be taken to reduce emissions of greenhouse gases and a global carbon tax should be introduced to make growth greener and achieve long-term sustainability.**

Chart 3-2: Impact of climate change on global GDP based on the integrated assessment models and the Stern report



Source: own compilation.

In relation to the cost of carbon, the most radical estimate is provided by Ackerman and Stanton (2012), who believe that by 2050 the social cost of carbon may rise to some USD 1,500. At the macroeconomic level – similarly to Stern, and contrary to the optimistic estimate of the DICE models – in 2018 the report of the UN's Intergovernmental Panel on Climate Change estimated global economic losses at roughly USD 70 trillion, i.e. almost 10 percent of global GDP, even with a lower warming of only 2 degrees Celsius (IPCC, 2018).

At the same time, the success of the environmental policy implemented for green growth does not immediately result in higher economic growth. In order to eliminate pollution, the whole society benefit of the interventions should exceed the cost of public policy. By supporting green innovation activities later on a technology may become available which makes it worthwhile to implement the public policy intervention even under high costs. Although the growth effects of the intervention are realised only later, after a transition period, public policy fostered sustainable growth over the entire horizon.

One distinct element of the green growth policy is that a global solution is required in the field of emissions cuts. If there is a harmonised international taxation policy, a carbon tax of the same rate is imposed on emissions in all countries. The disadvantage of local policies is that economic activity is mobile, and thus in the absence of coordination it can easily move between countries, thereby undermining the efficiency of the environmental policy.

In relation to the severity of climate change and the strictness of the environmental policy, **the fundamentally different results estimated by Nordhaus (1991, 2017), Stern (2006) and the followers of their school are attributable to several reasons.**

Since climate change takes place over the long run, over the course of centuries, assessment of the future bears particular importance (Chart 3-3). **In the early DICE models, the value of the discount factor quantifying the importance of future is too high, i.e. it undervalues the importance of future, as a result of which these models significantly underestimate the effects of climate change** (Stern, 2013).

In the integrated models, **economic growth is controlled by exogenous factors** in the single-product aggregated growth models, which ignores the role of innovation and also of sustainable growth through green innovations (Stern, 2013).

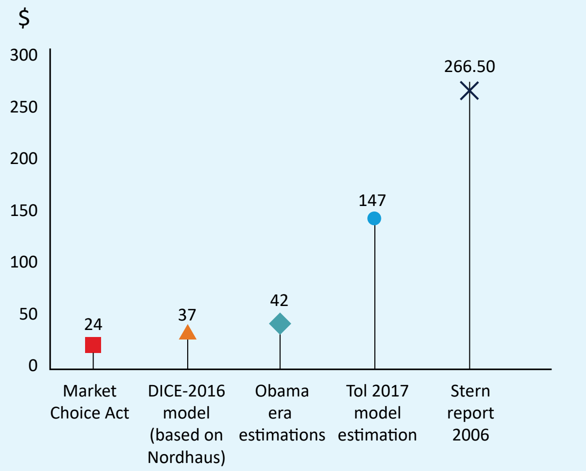
Due to the obsolete specification of the damage function, and to the simultaneous function relation between the inputs, the temperature and the condition of the environment have no impact on the subsequent periods and skip entire sectors (e.g. biosphere services, size of rainforests, etc.) in the analysis (Pindyck, 2017).

The early models **underestimate both the probability of disasters and the damages caused by such**, and only attach low probability to the risks: they ignore the degree of consequential damages caused by disasters, the breaks caused in the social and environmental capital, the destruction of physical capital, mass migration and war conflicts (Weitzman, 2012; Pindyck, 2013). Including the number of extreme hot days in the damage function alone doubles the estimated value of the social cost of carbon (Moore et al., 2017).

It is the shortcoming of the integrated models that the **changes caused by climate change should be examined both at the extensive and intensive margins:** namely, due to the warmer weather, consumers install more air conditioners, agricultural companies deploy more irrigation systems (extensive margin) and also use them more often (intensive margin) (Auffhammer, 2018).

The **geographic focus, i.e. whether the degree of damages is assessed at the national level, locally or globally,** is an important difference. While Nordhaus focuses on the developed industrial countries in his analysis, Stern's model presents – analysing the difference between the impacts on developed and underdeveloped economies – that due to their unilateral economic structure, dependence on agriculture, low level of technological development and weak adaptation capacity, **climate change has a severe effect primarily on underdeveloped economies, the spillover security risk of which, however, will also impact the developed world.**

Chart 3-3: Social cost of carbon based on different estimates



Source: own compilation based on the Stern report (2006).

The analyses of the past decades related to the trio of climate change, sustainable growth and environmental policy, differ substantially from each other. However, **most of the studies agree that the mitigation of the external impacts calls for the introduction of a carbon tax.**

3.2.3 RADICAL RESPONSE: DEGROWTH INSTEAD OF EMISSIONS?

In contrast to the green growth requirements, the latest and most radical response to the connection between sustainable growth and climate change is given by one of the schools of the *post-growth economy,* developed in the late 2000s, i.e. macro ecology. **The school of de-growth, formalised by the theory of Victor (2008) and Jackson (2009), fundamentally rejects the possibility of sustainable economic growth achievable by environmental policies.**

The de-growth theory supports new ecological economic models and approach, according to which, humanity needs to strengthen solidarity and cooperation, in addition to fundamentally changing our life and culture – changing consumer habits and reducing market competition.

The de-growth theories are based on the economic consideration that in parallel with the development of the modern economies, GDP and consumption expenditure increasingly ignore several elements of subjective welfare and sustainability, while they admit a variety of performances the positive impact of which on welfare is questionable. According to the interpretation of Jackson (2009) after an income per capita of USD 15,000 income growth no longer improves the welfare of the individuals and has hardly any effect on life expectancy or infant mortality. The data approximating production and consumption do not include, for instance, the social needs of people, the welfare impact of entertainment and leisure opportunities, the importance of access to information and digital assets, the importance of the health condition and the welfare impact of appreciation and learning.

According to the calculations of Victor and Jackson, with the current population and economic growth dynamics, the carbon intensity of GDP should decline by 7 percent annually, to reach the emission level of the 2000s by 2050. Thus, according to their conclusions, no green growth framework or climate protection policy whatsoever is able to offset climate change while maintaining growth (Jakob and Edenhofer, 2014). Accordingly, an economy should be created in which the biophysical reserves and processes are stable, and the raw material and energy flows remain within the ecological limits (Schneider et al., 2010).

Based on Victor's (2011) *LowGrow* model, growth "respects" the global limits of the global environment, i.e. it runs into a hard environmental limit. **Sustainable de-growth is a state where following a transitional period, economic output** – at much lower energy and commodity consumption needs than at present – **stabilises at a lower equilibrium level.** At the same time, the de-growth dynamics appear not only in the lower investment activity and lower emissions of greenhouse gases, but also in the decline in global inequalities. **At the same time, the introduction of a carbon tax is also essential in the de-growth framework, the rate of which is so high that it fully eliminates harmful economic production.** However, compared to the green growth reforms, this is not accompanied by a large increase in public spending, and thus it also yields no new types of innovations.

However, the present societies focus on the objective of continuous economic growth to such a degree that according to Kallis et al. (2012) a de-growth period may even lead to the collapse of societies. Hence, ecological economics must provide answers to questions such as how the social equilibrium of the world can be achieved without growth. In their analyses, the damages entailing decreasing production and consumption are offset by the social relations resulting from the increased free time and welfare, i.e. growth in social capital. However, due to its design, the welfare measurement system used today, i.e. the System of National Accounts, is unable to reflect the benefit of those (Bilancini and D'Alessandro, 2012).

The macro ecological theories use a radical approach to stop climate change: shifting toward an environmentally aware, sustainable world entails restrictions on the use of resources and CO_2 emissions, the introduction of limits on exploitation, the elimination of harmful investments and licensing only green investments, the reform of work organisation and income distribution, as well as revision of the role of trade and the financial system (Kallis et al., 2012).

All in all, the economic approaches analysing the relation of sustainable growth and climate change vary on a wide scale: Nordhaus' optimistic approach is now already obsolete, while the radical approach of the latest de-growth concepts cannot for the time being be regarded as a sufficiently elaborated framework.

Stern's much more pessimistic green growth framework – assuming major environmental losses, but supporting clean growth and government intervention to stimulate innovation – has become widely accepted. According to their analysis, the new green industrial revolution, correcting the market failures, may only be realised in conjunction with permanent government presence: the state can support long-term sustainable growth by tax policy, large-scale investments of low CO_2 emissions and fostering proper green innovations. Green growth thus achievable, in addition to making the absorption of resources more efficient, and can be realised in a new, innovative business world.

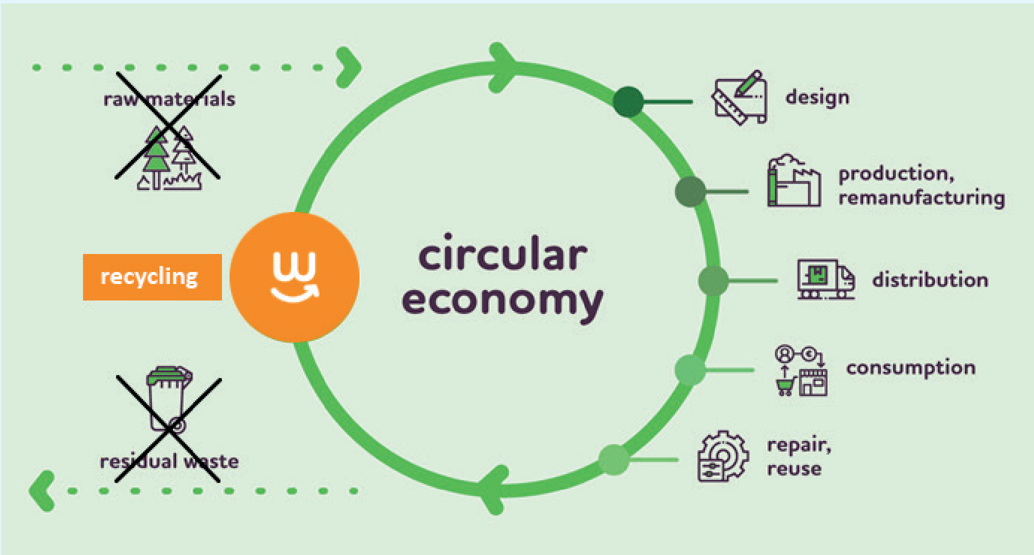
Box 3-1: Framework and practical implementation opportunities of the circular economy

One way to realise the new de-growth concepts in practical terms is the development of a circular economy. It hinders long-term sustainability that economic activities are dominated by competition, instead of cooperation. Furthermore, in the current social, economic and conceptual framework, the linear economic model fails to recognise the high economic, social and environmental costs of the exploitation, transformation and removal of resources. **However, the circular economy is neither the denial of market operation nor a "green" system that will never pay, but rather a new, novel economic and business model.** The purpose of the circular economy is to ensure that through conscious and precise planning the circle displaying the life cycle of the consumed products closes "seamlessly", without generating any waste during the manufacture and consumption of the products.

The advantages of the circular economy are summarised well by the European Environment Agency (EEA, 2016). Due to the decline in demand for imports and for primary raw materials, a circular economy results in **improving resource safety,** while in parallel with this **environmental load** and emissions of greenhouse gases **decrease**. The circular economy provides new opportunities for growth and innovation, and due to better resource efficiency, it also exerts a positive effect on financial savings, while the new employment opportunities also have social benefits.

The circular economy approach also necessitates innovative solutions by the government in order to operate the economy. In the circular approach more sustainable, resilient and open systems are created at the local level, while the local authorities play a dominant role in each phase of the functioning of the economy. **Local governments can foster new forms of cooperation between certain economic sectors and disciplines.** The objective of the circulation is to transform the attitude of economic agents at each point in economic production. In the **development of products**, it is not only aesthetics and ergonomics that matter, but also the possibility of repairing, transforming and recycling the products in the future, since in addition to being economical, they should also be recyclable and environmentally friendly. The government can encourage the market to develop resource-efficient and permanent, local solutions. On the other hand, during the **manufacturing of the product** it can cooperate with the other stakeholders in the sustainable procurement of raw materials and also in the various methods of the circulation of resources (industrial symbiosis, chemical industry borrowing procedure, re-manufacturing). Regulators have the opportunity to **influence the consumption habits** of households, companies and other organisations, through training, education, awareness, supporting the sharing economic concept, reuse and repair. Finally, during **recycling**, the local government plays a critical role in developing the waste collection scheme, increasing manufacturers' environmental responsibility and spreading the need for bio refining and composting.

Chart 3-4: Circular economy



Source: MNB.

Certain large companies have identified major business opportunities in the circular economy. For instance, one century ago the Belgian company *Umicore* was still the largest copper mining company of the Belgian colonies, while by now it has become one of the world's largest secondary raw material user. The *"pay per lux"* lighting offer of *Philips*, the Dutch light engineering and electronics company, relieves large companies of the procurement, maintenance, repair, quality control and waste management burdens: they only need to pay for the used volume of light (lux), everything else takes place in the global company's closed, "circular" system. *Caterpillar,* one of the largest US machine manufacturers, now deliberately designs its products in such a way that permits modernisation of them after a while instead of scrapping. The French firm Schneider Electric only uses recycled materials and more than 12 percent of its revenue now come from circular operation. *Adidas* uses recycled plastic fished from the oceans in an increasing volume of its products, while *Coca Cola* announced recently that it would sell several of its products solely in recycled PET bottles.

However, it is not only large companies that can do something for less by-products. The circular economy also offers major business potentials for small and medium-sized enterprises. A small British company, *Batoko,* produces swimming dresses and bathing suits only from plastic from the ocean, while 4ocean in Florida also manufactures bracelets from plastic fished from the oceans. The textile industry innovation of the Dutch startup company, *DyeCoo,* dyes clothing without water and overly harmful chemicals, and thus it not only uses less harmful materials, but is also able to produce the end-product faster, using less energy. The Australian company, *Close the Loop,* manufactures road surface – by 60 percent more durable than traditional asphalt – by recycling used printer cartridges, plastic and glass. For one kilometre of road it uses 530,000 plastic bags, 168,000 bottles and 12,500 empty printer cartridges. The American *Lehigh Technologies* manufactures construction base materials from decomposed rubber waste. The Danish *RGS90* produces construction insulator materials from porcelain and glass waste. While the Canadian startup company, *Enerkem*, produces biofuels from hydrocarbon extracted from waste. The Berlin-based startup, *Kaffeeform*, collects waste from coffee shops in the capital and produces recycled coffee cups from coffee-grounds, while the Danish *ecoXpac* manufactures biodegradable beer bottles.

However, the concept of circular economy can only be based on households' collective environmental awareness and on changing corporate business models. The thoughts of sustainability, green energy and no-waste have spread rapidly in the western part of Europe and in the highly developed countries of the world. As a result, in Germany, the Netherlands and the Scandinavian countries convincing and conviction have already reached such levels that a large part of the population is willing to use more expensive products and energy, if they are provably based on sustainability and global climate protection. Due to the income differences, this approach has not yet spread widely in the Eastern and Central European countries. **However, numerous examples show that the circular economy approach is a profitable business model and a significant take-off opportunity for the small and medium-sized enterprises of a country, the benefits of which the world will truly appreciate only in the future.**

3.3 Directed technological change and green growth

Since the financial crisis of 2008-2009, economic models relying more directly on the role of efficient government intervention than before have gained ground. Since purely market coordination-based growth models predict that sustainable economic growth cannot be achieved or can only be achieved under very strong assumptions, **green growth theories implemented by the state's environmental policy have become increasingly more popular** (Bowen, 2012, 2014; Jacobs, 2012). Based on green growth theories, the innovative state – looking beyond market trends – is also able to orient the direction of growth towards a future growth path it deems desirable, and thus the support of innovation also stimulates the innovation capacity of the entire economy.

It was Nordhaus (1973) who first introduced the **"backstop technologies"** as a production factor in his analysis, **which are able to replace the harmful production of non-renewable resources, or even the resource itself, with renewable resources and clean production.** An example of backstop technologies, already available for natural resources, is the solar and wind energy. Thus, the alternate technologies are already available today, but their exploitation is hindered because they are often not yet competitive enough to be widely implemented (Chakravorty et al., 1997; Pittel et al., 2014). **The application of backstop technologies will commence when the exploitation costs of those are lower than the revenues calculated based on market prices.**

Acemoglu et al. (2012, 2016) build their green growth models based on directed technological change by overshadowing harmful technologies and treating alternate, non-polluting technologies as growth drivers, which is the harmonisation of the relative prices of production factors (Hicks, 1932), the technological pressure and innovation limit (Kennedy, 1964) and the concept of directed technological changes (Acemoglu, 1992).

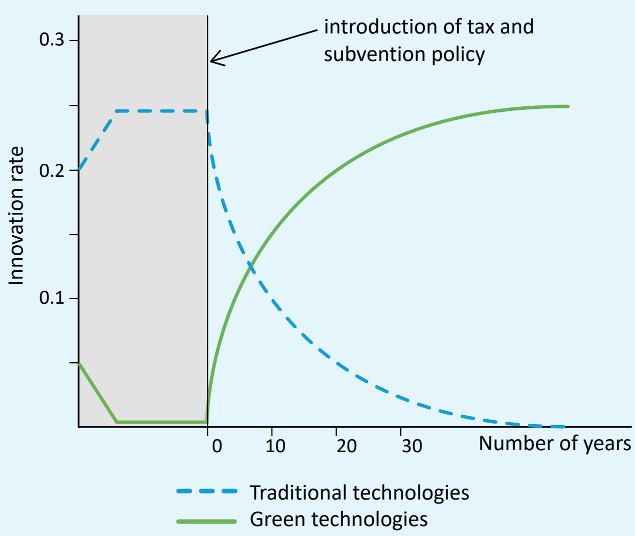
In the two-sector economy, **economic production harmful for the environment (causing pollution) absorbs natural resources, while clean (green) production preserves them.** It follows from market structure that **labour force flows**

where it receives higher wages, which, however depends on the marginal product of labour, i.e. on labour productivity. **Since polluting production is cheaper, it can offer higher wages than clean industries, and thus initially it is not worthwhile for the economic agent to invest or take a job in a clean industry.** Nature is present in the model only indirectly: the excessive use of resources reduces production, and ultimately environmentally unsustainable growth leads to an environmental disaster.

The economy is shifted from the harmful equilibrium that hinders future sustainable growth by environmental policy: **based on emitted volume, the government imposes a tax on the product of the polluting industry**, thereby changing the production costs of the companies producing the intermediate goods. The labour productivity of harmful production decreases, and thus it no longer pays to employ workers at the previous wages. **As a result, the labour force flows to the green industries, and thus the emissions of polluting production decrease and end** (Chart 3-5).

In the long run, due to the tax imposed on dirty industries and the decline in production, the aggregated output of the economy will become lower, but the probability of a climate disaster decreases as well. At the same time, economic growth remains positive, since the **government intervention modified only the distribution of the labour force and innovation tendency among the industries.** Aggregated innovation activity does not change, but more innovations appear in the clean industries than in polluting ones. **Following this, the innovation necessary for growth is realised in the green industries.**

Chart 3-5: Sustainable growth in the models of directed technological change



Source: own compilation based on Acemoglu et al. (2012).

State intervention adjusts market failures, prevents polluting industrial innovations and fosters the development of green sectors, thus resulting in sustainable, long-term economic growth.

The timing of the imposition of taxes, and the validity timeframe thereof is an important issue. Too early intervention by the government may lead to the devaluation of investments that are less polluting than expected, while postponement may entail major social welfare loss, if the production is more polluting than expected. **The validity timeframe of the tax is determined by the substitutability of the green and polluting industries' products.** If the final products of the polluting and clean productions are substitutable, taxes should only be effective until the total production changes over to clean innovation and output. If the clean and polluting industries and final products are supplementary in final consumption, the tax must be effective forever, otherwise the original equilibrium, undesirable for the society, will be restored.

Mazzucato (2013) and Mazzucato and Semieniuk (2017) analyse the practice of the developer, innovative state, depicting through examples from the historically successful, developed western world, how the state contributed to development in the large technological revolutions. They present how the state in Finland and the government in the United States financed the building of Nokia and Apple, Google and Facebook, respectively, the development of Tesla, or the invention of GPS and the internet, which were originally military technology tools.

The state with a targeted mission appears on sub-markets of high market risk, high capital intensity and uncertain payments, also in the area of electronic, pharmaceutical or biotechnological developments, thus orienting the market toward the future development path it deems desirable. **Accordingly, the state can play a major role in shaping development in case of the western world too, if it considers the benefits of green growth and looks beyond the market trends when it wishes to orient the direction of growth.**

Moreover, through the optimal combination of imposing taxes and strengthening propensity for innovation it can be achieved that in the long run sustainable growth is accompanied by higher aggregated output. The surge in clean technology patents, and the headway of new technologies may have spillover effects that impact the entire national economy.

The state has numerous instruments both in respect of taxation and subsidies depending on whether it wants to influence consumption or production. The carbon tax, the carbon dioxide emissions quotas and the introduction of emission-related penalty taxes are aimed at curbing polluting technologies, while increasing the petrol prices or the CO_2 tax of airfares are directed at consumers. **Green innovation by Hungarian companies and the propagation of clean technologies can be supported by several tools, such as investment tax allowances or research and development subsidies, while consumers may benefit from personal income tax allowances, tax credit or cash transfers.**

However, the local taxation of polluting industries has several international aspects, since as a result of taxes introduced on a stand-alone basis, the polluting production may easily move to another country with no regulatory system. The model of Hemous (2012) presents the two regional extension of the directed technological change, where due to the carbon tax imposed in the *Global North* region on the emission of pollution the polluting industries move to the *Global South* region, where the degree of polluting innovations increases, while Van den Bijgaart (2017) expands the model with countries' tendency to innovate, where in addition to the size it is also important how far the polluting and green innovations at industry level are from the innovation limit. At the same time, in the empirical assessment of the model Van den Bijgaart (2017) finds that it is not sufficient if only the developed economies (United States or the European Union) are committed to boosting green innovation. **Based on this, in the interests of the global success of directed technological change, the majority of the countries that signed the Kyoto Protocol should participate**, since due to the size of the countries this is the only way to achieve economic coverage that ensures sustainable green growth.

However, the less developed states of the world at present are still in the intensive growth phase of emissions, which complicates acceptance of a global response to climate protection. Aghion and Jaravel (2015) examine the question from the aspect of emerging countries, and propose that for the less developed countries – which are worried about the opportunity of economic convergence and thus reject the introduction of global carbon dioxide quotas – even copying and imitating the already developed technologies provides an opportunity for development, and at the same time it would also result in a major technological advance for them.

Based on Aghion et al. (2016), the **impact of path dependence and local knowledge spread is significant in green innovation by corporations:** companies that have innovated in the past are later much more likely to register green patents again than those that have not. Moreover, companies which operate next to corporations that are successful in clean innovation are much more likely to make innovations in clean technologies themselves.

At the same time, open access to patents may also have a negative impact on corporate innovation, since if anybody can easily access technological knowledge, the innovator is unable to earn a profit on its investment, while for the copying company it is not worthwhile to make developments from the outset. **In order to manage climate change, it is also necessary to revise the traditional patent scheme developed to safeguard companies' innovation activity.** Instead of safeguarding corporate innovations, knowledge sharing should become the focus within the framework of green growth. Hall and Helmers (2013) examine the positive impact of Eco-Patent Commons, **a free-of-charge patent portfolio** established in 2008, on several large companies, such as IBM, Nokia and Sony. **The initiative, which accelerated environmental protection and fostered further innovation ceased in 2016, the reason for which** – in the opinion of Contreras et al. (2018) – was the non-transparent monitoring of the use of the patents and thus the non-transparency of participation. Today, car manufacturer Tesla publicly shares its patent of the electro engine with the world, in order to facilitate the changeover of the automotive industry to the manufacture of environmentally friendly cars as soon as possible.

Box 3-2: Presentation of the German green growth programme

In September 2019, the parties of the German grand coalition agreed on the adoption of a comprehensive, state-directed growth-stimulating climate package. The objective of the German government is that by 2030 emission of greenhouse gases falls – compared to the level of 1990 – from 866 million tons to 563 million tons, i.e. by 55 percent. The government plans to spend EUR 54 billion by 2023, while over the entire period – until 2030 – more than EUR 150 billion will be spent on the programme in the form of tax subsidies, allowances and public investments.

The part of the programme **impacts the consumption patterns of households.** It causes the prices of fuels entailing higher CO_2 emissions, such as gas and heating oil, and fuel prices to rise, and implies a decrease in electricity prices. From 2026, the deployment of oil stoves will be prohibited, and the state will provide a 40- percent subsidy for the replacement cost of the old heaters.

Targeting the pollution emissions of companies' production, a local quota trading system – similar to the European Union's CO_2 emissions trading system (EU ETS) – **is created to "tax" polluting production**, exclusively for German companies. Based on this, each company – in line with its own pollution emissions – based on the utilisation of the quotas applicable to it, may sell its unused quotas or buy additional quotas on the market, as necessary. The unit price of carbon dioxide, in a continuously rising scheme, will be aligned with European prices, which starting from EUR 10 in 2021 will rise to a target price of EUR 35 by 2025 in a tiered system. Thereafter, from 2025, in accordance with market conditions, they may fluctuate between EUR 35 and EUR 60.

Based on the programme, 65 percent of the German energy mix will come from renewable resources by 2030. Thus, the **state supports the penetration of clean technologies**: it provides substantial subsidies for the spread of renewable energy and for the establishment of high-capacity wind farms and solar cell parks.

The programme under review **targets a substantial transformation of community and long-distance transport,** i.e. the sector with the highest CO_2 emissions. **On the consumer side,** the subsidy for the reimbursement of the travel costs of consumers commuting with the use of public transport is raised, as a result of which those commuting between their home and work receive an allowance of 35 cents per kilometre from their income tax. Tax allowances for the purchase of e-cars cheaper than EUR 40,000 are extended until 2025, and thereafter the continuous subsidies as well. From 1 January 2020, the sales tax on air travel will be raised, while the sales tax on railway transport will be reduced from 19 percent to 7 percent.

In the public sector, the Deutsche Bahn public railway company may receive annually a public capital injection of EUR 1 billion (HUF 330-340 billion) until 2030 for the modernisation and expansion of the railway network, which – together with the reduction of the sales tax – may make railway competitive. In addition, the road toll for trucks will be increased from 2023, in order to encourage the sector to turn to cleaner drive systems through the costs of the largest emitter's road transport. Significant amounts are spent on the **support of green innovations**. For instance, the manufacture of energy cells is subsidised with EUR 1 billion. The package will be expanded by the end of the year also with other elements related to sustainable water balance, smart electronic developments, and with targeted SME subsidies.

The empirical documentation of directed technological change is extremely broad; in the past decades several analyses assessed the impact of oil and energy world market prices, regulatory requirements and tax changes, consumer tax allowances, direct financial support and the introduction of tradable CO_2 quotas on green innovations.

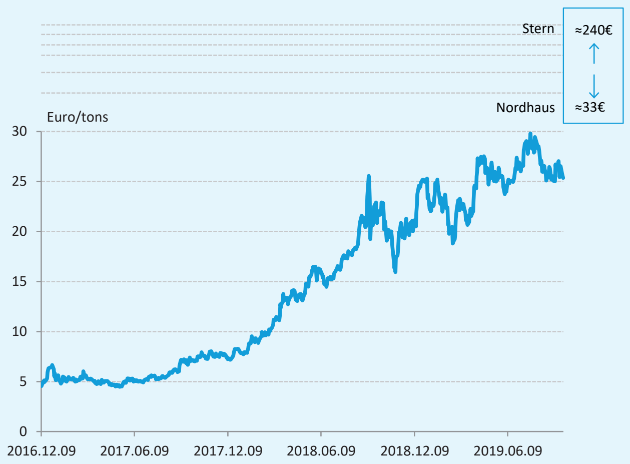
Corporate reactions

Newell et al. (1999) and Popp (2002) **examine the effect of world market prices on corporations' energy efficiency innovations.** They demonstrate that with a rise in the world price of energy, the number of patents aimed at energy efficiency soars. In addition to several different industries, e.g. an increase in oil prices has a significant impact on the number of energy efficiency innovations in the air conditioning industry. Newell et al. (1999) also demonstrate that as a result of **energy efficiency labelling, introduced under regulatory pressure**, the role of innovations aimed at energy efficiency increased in the air conditioning industry.

Crabb and Johnson (2010), and Hassler et al. (2012) examine the **impact of world prices of oil on innovations in the automotive industry**, and find that the rise in fuel prices fosters technological innovations that reduce emissions. Haščič et al. (2009) demonstrate that while fuel prices foster technological innovations reducing emissions, government regulation impacts new types of innovations as well. Based on corporate data, Aghion et al. (2016) examine the impact of **regulatory tax content in fuel prices on innovations related to internal combustion and hybrid/electronic vehicles** in three leading economies of the world (EU, Japan, USA) between 1985 and 2005. They find that as a result of a 10- percent increase in fuel prices, patents registered for electronic and hybrid drive increased by 10 percent, and innovation related to internal combustion engines decreased by 6 percent. **Maximisation of the CO_2 emissions of car manufacturers at fleet level** is also a good example of the orientation of innovation by regulatory measures.

Johnstone et al. (2010) **analyse the impact of the government's environmental policy on innovation in the case of renewable energy**, based on panel data from 25 countries. According to their results, active government climate policy has a positive impact on green patents: wide-ranging policies, such as **tradable energy certificates** are efficient in the industries competing with fossil fuels, while targeted subsidies, such as the **initial green investment grants** may be efficient in the area of technologies of higher fixed cost, such as solar energy.

Chart 3-6: Carbon dioxide prices



Source: Bloomberg.

Based on the **ETS, which is primarily meant to restrain CO_2 emissions from industrial production**, participating factories may emit pollution up to a predetermined limit and sell the unutilised emissions at auctions, while those whose emissions exceed the predetermined level may buy additional CO_2 quotas also at auctions (Chart 3-6). Calel and Dechezlepretre (2016) analyse the efficiency of the European Union's tradable emission quotas (Emissions Trading System – ETS) and they find that among the **companies regulated through the ETS, clean innovation patents rose by an additional 10 percent and did not crowd out other innovations.** Martin et al. (2011) also came to a similar conclusion based on the series of interviews conducted with the managers of several hundred of European companies. **Cui et al. (2018) prove the relevance of the directed technological change based on the Chinese quota trading system:** having examined the data for the period 2003-2015 they found that the new patents resulting in low CO_2 emissions increase the number of clean innovations by roughly 19 percent in the areas trading with emission quotas, resulting in a 1.5 percent decrease in the carbon intensity of the Chinese economy. Generally, Constantini et al. (2017) also arrive at the same result. According to their estimate, a rise of 1 percentage point in green innovation results in a decrease of 0.08 percent in CO_2 emissions intensity.

Consumer reactions

Instead of regulating production, channelling consumer choice depends strongly on the design of the programme. For the efficiency of the programmes, the regulator's precise knowledge of consumers' behaviour, the price elasticity of consumers and the necessary degree of subsidies are essential. Overly generous subsidies or excessive taxation can easily undermine the efficiency of the programme.

d'Haultfoeuille et al. (2014) analyse **the orientation of consumers' car purchasing habits by government regulation**, based on the 2008 French *Bonus/Malus écologique* system. In addition to the **discount** of EUR 1,000 for the purchase of less polluting new cars, an extra tax of EUR 2,600 was imposed on the most polluting cars. **The programme had negative impact on the aggregate pollution emissions both at the extensive and intensive margin:** as a result of the programme the number of car purchases rose by more than 13 percent, and customers also travelled more by cars with lower consumption. Sallee (2011) came to similar conclusions: having examined an American programme from 2005, he found that the programme with a total cost of USD 800 million, aimed at the purchase of hybrid cars, on the whole, had no emission-reducing effect, since consumers scheduled their purchase and demand increased to such a degree that it offset the original environmental objectives. Chandra et al. (2010) obtained a similar result when examining the **tax allowance programme** related to hybrid cars in Canada between 2005 and 2007. During the subsidy period, only roughly 26 percent of the cars sold can be attributed to the allowances, and thus the programme reached many consumers who would have bought a hybrid car or would have replaced their car anyway. Mian and Sufi (2012) examine the impact of the large-scale **used car replacement** programme, announced in the years of the 2008–2009 economic crisis: consumers schedule their purchase in the knowledge of the expected benefits of the programme, as a result of which, during two months of the subsidy period 370,000 such new cars were purchased that otherwise would have been purchased only in the next one year. **Thus, although the direct subsidies granted to consumers support the cleansing of the car market, they often do not achieve the expected structural impact.**

Gerlagh et al. (2018) in their analysis performed on the 2001–2010 data of 15 EU countries, and Cicconne (2018) based on micro data of a Norwegian public policy programme both found that the **higher fuel tax content and the rise in the carbon dioxide sensitivity of car registration taxes** leads to the purchase of cars with better fuel efficiency, i.e. in the first study it resulted in 6.5 percentage point higher diesel purchases instead of petrol engine cars, while in the latter case the market share of diesel cars rises by roughly 20 percentage points as a result of the regulatory tax change.

Several analyses examine **what is the most efficient form of government support to increase the purchase of electric and hybrid cars.** Using US data, Gallagher and Muehlegger (2011) find that between 2000 and 2006 in case of promoting the purchase of hybrid cars, sales tax exemption had more than tenfold larger impact compared to income tax credits. Estimating a structural equilibrium model on data from 1999-2005, Beresteanu and Li (2011) came to the conclusion that 5 percent of the hybrid car sales are attributable to income tax allowances, while in 2006, 20 percent of new car sales are attributable to tax credits. By estimating a structural equilibrium model, they come to the conclusion that had oil prices been in 2006 at the level of 1999, the number of hybrid cars sold in America would be 37 percent lower. Sallee (2011) deems the **income tax credit** scheme to be efficient, while Diamond (2009) based on the analysis of US data, and Chandra et al. (2010) based on the analysis of Canadian data regard **one-off discounts** as the most efficient incentives.

Since the industries burning fossil fuels still operate much more cost efficiently than the sectors producing renewable energy, today initial installation subsidy is granted by the governments in more and more countries (e.g. in California) or subsequent production-based subsidy (e.g. in Germany) for solar panel developments. Burr (2014) examines **the impact of government subsidies granted for solar panel developments,** and he finds that the **preliminary investment grants**, depending on the capacity of the solar cells, are more efficient, result in more installations and generate less welfare loss than the **subsequent, production-based subsidies**. Hughes and Podolefsky (2015) examine the impact of a programme in California, the California Solar Initiative, between 2007 and 2012. During the programme with a total cost of USD 437 million, 5-25 percent of the installation was paid by the regional government, a discount of 7 percent resulted in 11-15 percent new deployments, while 57 percent of roughly 100,000 new deployments were realised solely as a result of the programme. The new panels of lower emission reduce CO_2 emissions by 2.98-3.15 million metric tonnes, and NO_x emission by 1,100-1,900 tonnes at a horizon of 20 years. Examining the impacts of a Belgian solar panel construction programme between 2006 and 2012, de Groote and Verboven (2019) obtain similar results: in the programme granting subsidies depending on future production only slightly more than 8 percent of households installed solar cells by the end of the programme. In relation to the installation of solar cells, the weight of the conversion between immediate investment costs and future benefits plays a major role: according to their estimate, consumers substantially underestimated the future benefits from renewable energy, and thus the programme could not be successful. In his global model, Gerarden (2018) estimates that 49 percent of global solar cell installations between 2010 and 2015 were realised as a result of government subsidies, while roughly 32 percent of the total solar panel installations is attributable to German subsidies only. **Accordingly, in the area of state aids for solar cells the initial installation subsidies may definitely be deemed efficient.**

Based on the empirical results of directed technological development, it becomes clear that taxes have positive impact on curbing harmful technologies in the corporate sector, while subsidies have a positive impact on the penetration of clean innovations. The regulatory measures targeting households usually have high costs for the entire society and do not target the selected layers well enough. If the regulator does not know sufficiently the households' price elasticity and their propensity to consume, the programme can easily become inefficient. Furthermore, no such spillover effect can be identified according to which the purchase of cleaner products encourages companies to offer cleaner products. **On the**

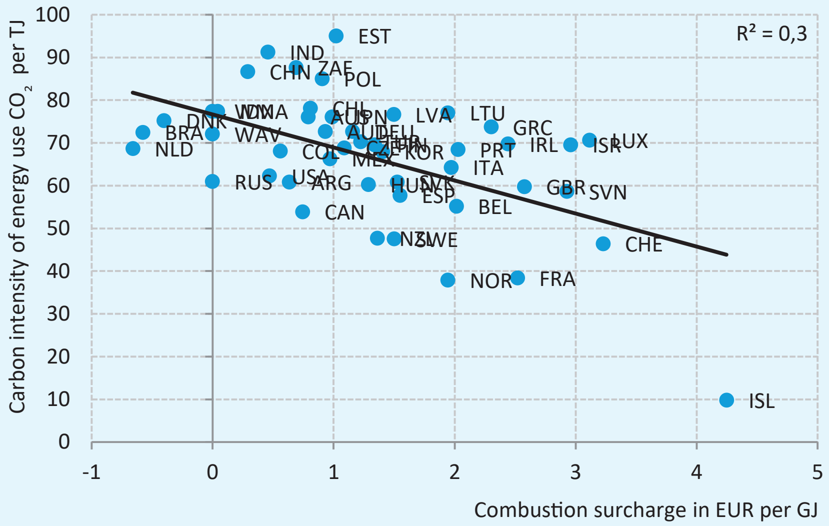
whole, the government's environmental policy can only be successful by applying a combined set of instruments: in addition to efficient fiscal policy measures, it is necessary to orientate the norms, generate and disseminate information, provide education and exert moral influence, as well as industrial and innovation policy related to environmental protection.

With the implementation of an optimal set of economic policy instruments, it can be achieved that in parallel with curbing polluting technologies, clean technologies gain ground, which on the whole results in lower CO_2 emissions and ultimately in sustainable green growth.

Box 3-3: Empirical assessment of the impact of energy taxes on CO2 intensity

Based on the theories, the relatively higher tax imposed on fossil energy sources – compared to wind, solar or water energy – may foster the technological changeover. A differentiated tax regime may be efficient to ensure the development of an appropriate price mark-up for energy produced by non-renewable resources. This may function as a proper incentive for the public and private sector to use their resources for the exploitation of renewable resources. However, the available data do not always support the foregoing. In its latest publication, the OECD examines the effects of carbon dioxide taxes imposed on the prevailing energy prices in developed countries on cross-sectional data. Based on their results, regarding the tax rate, the largest difference exists in Iceland, Switzerland, Luxembourg and Israel. In these countries the tax imposed on energy generated by renewable sources is close to EUR 0, while on fossil sources it is around EUR 3.5-5. By contrast, in Indonesia, China, the United State and Columbia – showing up at the end of the list – the difference between the two taxes is negligible. Finally, in the analysis they examined the relation between the surcharge and the economy's CO_2 intensity. The results confirmed the theoretical relations: if the government increases the difference between the taxes imposed on fossil and renewable energy sources, aggregated CO_2 intensity also declines. However, along with the results, it was also emphasised that in most of the countries – including also several developed economies – governments still have substantial room to develop proper incentive schemes.

Chart 3-7: Relationship between CO2 intensity and the surcharge on fossil energy sources



Note: The measure of carbon dioxide is tonne CO2/Joule.
Source: OECD 2019.

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4 Data revolution and environmental sustainability

Transition to the green growth scenario may be fostered by the cutting-edge technology of the near future both in the economic policy and for business enterprises. The collection of large amounts of data and the smart use thereof offer a number of benefits for the economic sectors: according to empirical results, big data and the activities related to the analysis thereof remarkably increase the productivity of companies.

The role of big data is not only important for technological progress: it has also economic relevance. In the past decade, green and sustainable growth (in addition to preserving our natural assets) and technological progress through big data have received special attention. In addition to enhancing corporate productivity, big data also facilitates the environmentally sustainable and socially acceptable development of low CO2 emissions, supporting the creation of environmentally friendly products, industries and business models and thereby further improving standards of living. Due to data availability, overproduction and overconsumption may be reduced. By optimising production processes and decreasing overconsumption higher productivity and greater savings can be achieved.

In this section, we review the current status of the industries with the largest CO2 emissions, examine which technologies are already available now and which one will become dominant in the near future, relying on which green growth in the examined sectors can be achieved. During the industrial transformation induced by the green industrial revolution, modern technology based partially or entirely on renewable energy sources gains increasing ground – in addition to the efficient utilisation of natural assets and the protection of the environment – in the energy sector, transportation, manufacturing, agriculture and also in the services sector.

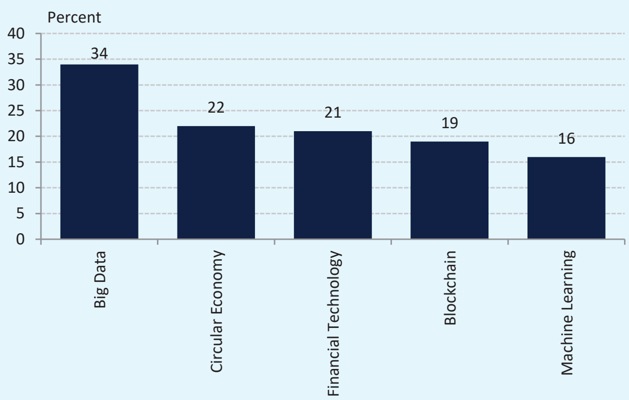
This chapter focuses on three technologies. The first one is the smart grid, which reduces the overload of the electrical network and provides higher security of supply and lower operating costs. The expansion of car sharing can reduce carbon emissions significantly by curbing car ownership and decreasing traffic. According to the expectations of Morgan Stanley, the rate of car sharing on public roads may reach 20 percent by 2030. As the mega-trend of urbanisation continues and based on the forecasts, the proportion of the world's population in cities is likely to rise to 70 percent by 2050. As a result, urban development is essential, which can be facilitated by the concept of smart cities. Implementing smart city technologies will result in more intelligent, more sustainable and more efficient urban environments, which ultimately leads to higher living standards.

4.1 Impact of data on productivity

Big data is an often used notion, nevertheless it has no commonly accepted definition. Gartner.com defines the notion in a 3V approach, according to which big data is the entirety of such large Volume, Variety and high Velocity data that are used for decision-making and for the better understanding of processes, but this requires cost efficient and innovative methods to retrieve the information. De Mauro et al. (2016) describes the notion as an information tool, the management of which requires special technology and methodology. In their definition, a fourth V, i.e. Value, also appears.

Transition to the green growth scenario may be fostered by the cutting-edge technology of the near future both in the economic policy and for business enterprises. Based on a 2019 questionnaire by Bond,[15] prepared on the basis of the opinion of employees responsible for international development in 37 countries, **the technology that best facilitates international development and (environmental) sustainability is big data** (Chart 4-1). However, the circular economy, fintech developments, blockchain technologies and the application of machine learning are also important for the purpose of the sustainability of growth (Wilkinson, 2019).

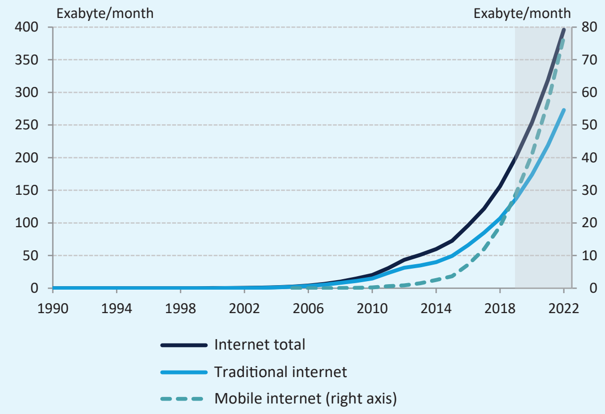
Chart 4-1: Top 10 technologies that contribute to development, results from 2019



Note: the percentage of responders mentioning the correspondent technologies.
Source: Bond, MNB compilation.

We live in the age of data avalanche (Wilkinson, 2019). As time progresses, data increase exponentially; based on IBM's 2017 estimate, 90 percent of the data at that time existing were generated in the previous two years (Techjury, 2019). **Global internet traffic, together with the traditional internet, started to increase exponentially in the early 2000s, and traffic is now already close to 200 exabyte/month** (Chart 4-2). This is roughly the equivalent of 50 billion DVD films, 54,800 billion MP3 format songs or 960,000 billion books of 200 pages on average.

Chart 4-2: Development of global internet traffic



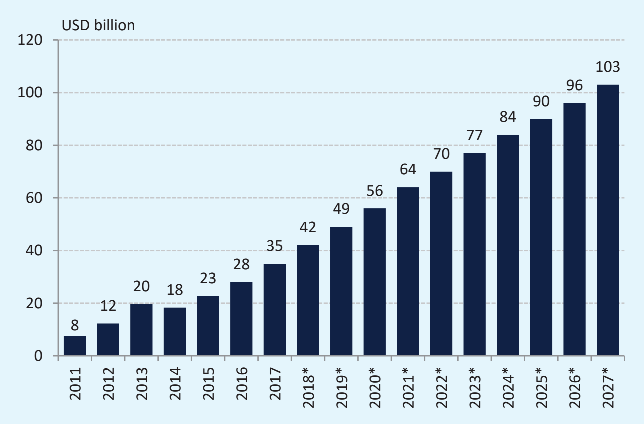
Note: The grey area denotes the internet traffic forecast for the period 2019-2022.
Source: Cisco VNI, 2017 Update.

Globally, the ratio of regular internet users within the population rose more than sevenfold compared to 2000, to 48.6 percent. The same ratio among the OECD countries is almost 80 percent according to the World Bank's calculations, which represents threefold growth compared to the start of the millennium. According to the research by BroadBandSearch, Google executes 40,000 searches per second, which comes to 3.5 billion searches per day. Compared to 1999 this is an enormous increase, as it then took 1 full month for the Google search engine to browse 50 million websites. According to the forecasts, by 2020 mankind will have data of more than 40 trillion gigabytes, while by 2022 twice the present monthly volume will be carried out on the global internet network, while mobile internet traffic will treble. **The growth in the online data traffic is a good illustration of the spread of the internet, which – supplemented with digitalisation and automation – fundamentally changes the behaviour of economic agents.**

As a result of the data explosion, the revenues of the big data market – based on the latest forecasts – will triple by 2027: while in 2017 the revenue amounted to USD 35 billion, according to the forecasts, by 2027 it may exceed USD 100 billion, which represents an annual average growth rate of more than 11 percent (Chart 4-3).

15 – British network, which links the organizations responsible for international development. https://www.bond.org.uk/about-us

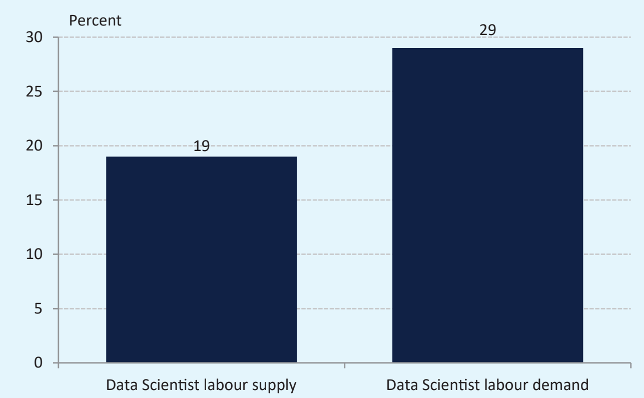
Chart 4-3: Growth in the revenues of the big data market; global forecast, 2011–2027 (USD billions)



*Note: *forecast.*
Source: Forbes, Statista, Wikibon, MNB compilation.

The big data phenomenon is also substantially transforming companies' labour market demand: it creates new jobs in the quantitative professional areas requiring high qualifications. Depending on the availability of the data and due to connecting the data networks, demand for employees with IT qualification increases considerably. In 2018, on the Indeed job search site, there were 29 percent more data technician open positions compared to the previous year, while compared to the data from five years ago, i.e. 2013, the demand for employees engaged in large data systems rose by roughly 350 percent.[16] By contrast, in 2018 the supply of data technicians in annual terms rose only by 19 percent (Chart 4-4), and thus the low ratio of experts can be identified as a material risk.

Chart 4-4: Change in the demand and supply of the big data labour market in 2018, based on announced jobs and jobseekers

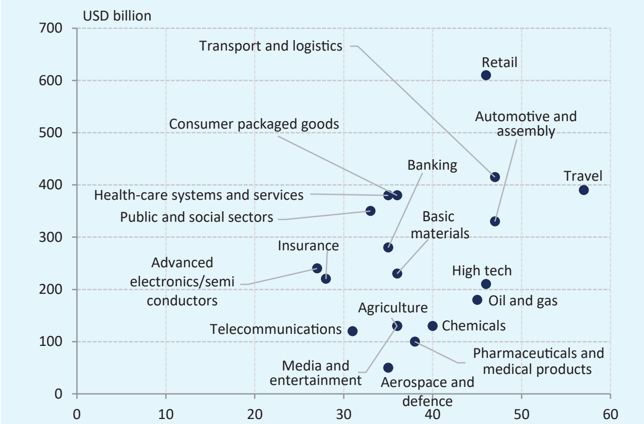


Source: searchbusinessanalytics.techtarget.com, Indeed, MNB compilation

Collection of data in large volumes and the smart use of such data offers several benefits for economic sectors: the general government, corporate and household sector all benefit from the positive impacts. Companies that deem database building important and use the resulting value and information in their business processes, are more productive. On the other hand, companies that do not build on the knowledge originating from big data fall behind in competition and lose market share.

The processing of large volumes of data is conditional on using artificial intelligence (AI). **At macro level, by 2030 artificial intelligence (AI) will generate 16 percent of the annual GDP globally** (Economist, 2019b). Figure 4-5 shows that AI has the most positive effect on the efficiency of retail trade, transportation and logistics. The forecast points to an efficiency gain of USD 600 billion for the former and USD 400 billion for the latter. They are closely followed by travel, healthcare system and services, the community and social sector, and the banking sector. AI generates the highest ratio of profit in travel, transportation and logistics, reaching 57 and 47 percent, respectively. The high tech sector, the automotive industry and assembly, retail trade and the oil and gas industry also register outstanding AI efficiency.

Chart 4-5: Potential annual efficiency gain from artificial intelligence (AI)*, globally, by sectors, as a percentage of AI/big data and data analysis



*Note: *The estimation is based on 18 existing techniques. Y scale: gains from AI, X scale: gains from AI as a percentage of data analytics.*
Source: McKinsey, The Economist, MNB compilation.

According to the empirical results, big data and the activities related to the analysis thereof increase corporate productivity. Examining the data-driven corporate decision-making, based on Müller et al. (2018), instruments related to big data result in **3-7 percent productivity growth**, while according to the calculations of Brynjolfsson et al. (2011), **the application of big data results in 5-6 percent corporate productivity growth on average.** According to Bakhshi et al. (2014), corporate productivity rises by **8 percent as a result of using online**

16 searchbusiness.techtarget.com

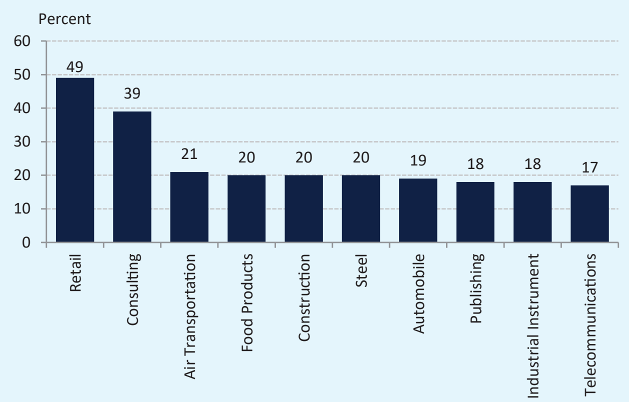
data, while McKinsey's (2016) own global questionnaire-based survey measured the initial impact of big data investments on profit increase at 6 percent, while its 5-year impact at 9 percent on average.

Bughin (2016) demonstrates the integration of data in the production function. In his model, economic output depends in a different way on capital stock and labour force, independent of the data, and on the capital investments and labour force using big data. According to his results, **big data investments in the area of IT and the labour force are of a supplementary nature, and boost productivity by 5.9 percent on average.**

Based on another approach, **big data in fact contributes to increasing GDP and productivity as an intangible asset, with the knowledge stemming from it** (Goodridge and Haskel, 2015). Information from raw data is first created in the data generating sector, which becomes knowledge in the knowledge generating sector, and is ultimately used in production. According to their results, **in the United Kingdom, big data increased the growth in market services only by 0.02 percent between 2005 and 2012; however, based on their forecasts until 2025 it may generate growth of 0.1-0.3 percent annually**.

Examining the Fortune 1000 companies, Barua et al. (2010) came to the conclusion that a **10-percent rise in the usability of data results in average growth in sales revenue/person of 14.4 percent. The strongest impact can be seen in the retail sector, followed by the consulting sector** (Chart 4-6). In addition, the impact exceeds the average also in the area of air transport, food products, construction, steel industry, car manufacturing, publishing, industrial instruments and telecommunications.

Chart 4-6: Impact of 10-percent growth in data usability on productivity (sales revenue/person)



Source: Barua et al., MNB compilation.

The skills of the labour force are as important as the usability of data. Based on the LinkedIn database, the **productivity of companies that hired employees with big data skills was 3 percent higher on average (Tambe, 2014).**

Overall, it can be stated that – based on the literature – the effect of big data on productivity is between 5 and 10 percent (OECD, 2015).

However, data-driven innovation has a destructive nature, which can also be referred to as "creative destruction" (OECD, 2015). Creative destruction causes restructuring in economies, which significantly affects the labour market. **For large, developed economies, it will be a challenge to capitalise on the benefits stemming from creative destruction for several reasons.** On the one hand, a substantial volume of the tasks of the middle class are being automated, which will affect not only manual labour, but also the tasks requiring high intellectual skills (e.g. an algorithm can diagnose the disease based on the symptoms and other complex data, or a loan assessment is performed by an automated model).

At the same time, the use of big data presents numerous optimisation opportunities not only for the general government and the business sector. Data may offer numerous benefits for consumers as well: they reduce transaction costs, facilitate the search for and finding of products and services suitable for us through personalised offers. On the other hand, **due to increased competition, prices approximate each other**, and generally decrease; furthermore, product quality increases due to the feedback received. We can also achieve a generally **better quality of life, e.g. receive better health services due to the tracking of data from ourselves** ('quantified self') or relying on real time traffic data we can optimise our movements and shorten the time wasted in traffic jams.

Box 4-1: Contribution to economic research and methodology

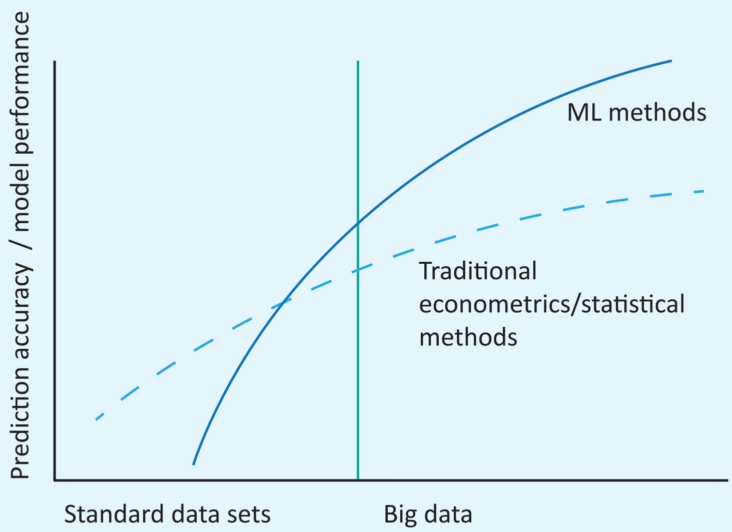
Large, complex datasets, from which we can retrieve valuable information, expand our knowledge of the world. The contribution of big data to economics is significant, due to the fact that aggregated data become decomposable, and a number of questions become clearer for policymakers. Since we can observe economic phenomena more efficiently, it will be more and more easy to estimate the impact of policies. This not only facilitates the testing of existing economic theories, the development of new ones also becomes simpler (Harding – Hersh, 2018).

Questions also change in the research – "why" is replaced by "what". In practice this means that the role of experts is revalued; it is no longer important to understand, for instance, why consumers prefer the respective product – the most important question is what they like. On the other hand, data scientists come to the front in many places, although this does not mean that professional experience will not matter at all in the future, only that specialist skills become less important (Cukier – Mayer, 2014).

New analysis methodologies, such as machine learning (ML), are more and more common. **ML methods improve the out-of-sample estimates, i.e. improve forecasts.** This partly originates from the aforementioned phenomenon; the search for causal relations (i.e. the question of "why") lose significance to the benefit of the simple correlations (the question of "what").

The performance of the econometric methods on small sample, traditional datasets outstrips the machine learning techniques (Chart 4-7). **However, in parallel with the rise in the elements of a sample ML methodology performs better and better, and finally outperforms the econometric methods.**

Chart 4-7: Performance of machine learning and econometrics upon increasing the number of elements in the sample



Source: Harding – Hersh 2018, MNB compilation.

The econometric approach primarily focuses on the statistical, data generating process (Table 4-1). By contrast, machine learning does not intend to explore the data generating process, but is rather built on algorithms. Econometrics focuses on theory, while ML on data fitting. At the first, the model is selected on the basis of the fit within the sample and the parameter significance, while in the latter along the cross validation of the out-of-sample estimate. Thus, econometrics is strong in the identification of causal relations and small sample analysis, while the ML technique is strong in forecasting and large sample analyses.

Table 4-1: Comparison of econometrics and Machine Learning

	Econometrics	Machine Learning
Approach	Statistical: data generating process	Algorithmic: we do not know the data generating process
Motivation	Theory	Data fitting
Focus	Hypothesis testing, interpretability	Predictive accuracy
Model choice	Parameter significance, in-sample fit	Cross-validation of predictive accuracy on partitions of the data
Strengths	Causal relationships	Prediction
Sample size	Performs better on small samples	Performs better on big samples

Source: Skrainka (2016), MNB compilation.

However, the importance of big data goes beyond the economic benefits. It not only appears in industrial developments and changes economic methodology, it also makes useful contribution to development in several other areas as well. The methodology of theoretical analyses and simulation is also supplemented by data mining in scientific research. It also facilitates interdisciplinary research, and the data science on its own as well is a cross-border field, combining the theory and methodology of several disciplines. It is worth highlighting its role in national developments; **in the modern globalised and digitalised world, the development of the national security cyberspace may be of strategic importance.** It helps us better perceive the present, and thereby it becomes easier to track down a wanted person or track him in real time, and in addition, the real time assessment of a marketing campaign also becomes possible. **It also helps forecast the future; however, future trends are useful not only in the area of economic developments, but also in restricting the spread of epidemics** (Jin et al., 2015).

4.2 Possibilities for the application of big data in the most important industries

Economic progress and industrial transformation in conjunction with economic development is a phenomenon that has been documented for decades. Special attention was paid to this topic in the 2017 Growth Report. **The weight of the agricultural sector typically declines on the economy's development path, and the proportion of industry moves on an inverted U-shaped curve, while the services sector shows steady growth.**

As a result of the green industrial revolution implemented as the consequence of directed technological change, industrial transformation continues. The role of agriculture and manufacturing is expected to decrease moderately, while the weight of the energy and services sector may increase further.

In addition to conserving natural resources, the use of technologies created as a result of big data and the new megatrends may strengthen structural transformation. All of this may be further supported by the wider application of more material-efficient technologies, automation, stricter environmental policies and regulations.

In the following, we review the current status of the industries with the largest CO_2 emissions and examine which technologies are already available now and which ones will become dominant in the near future, based upon which green growth can be achieved in the sectors examined.

4.2.1 ENERGY SECTOR

The energy sector is already in a state of transition: despite the rising exploitation and utilisation ratio of oil, coal and gas, **the share of renewable energy is also increasing dynamically in parallel with technological innovations** (Chart 4-8).

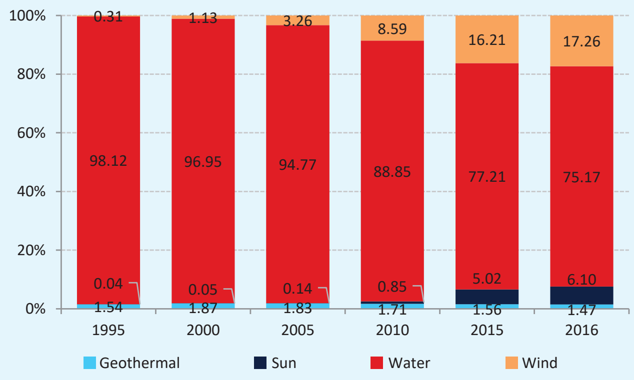
In the energy sector, there is significant potential to increase efficiency and technological developments related to smart metering and big data may offer solutions. By forecasting energy consumption more precisely, increasing efficiency and reducing losses, the sector's energy intensity could be reduced substantially.

Based on the forecasts, 75 billion electronic devices may be installed in the energy sector by 2025, which – via their interconnectedness – provide valuable information to users, companies and public service providers. Digitalisation of the sector may substantially promote the penetration of renewable energies, since the application of big data boosts the security of investments and facilitates professional risk management and standardised portfolio management. As a result of this, by 2030 the share of renewable energies may double, which – based on the calculations of the International Renewable Energy Agency (IREA) – would result in a 1-percent increase in global GDP. In addition to the foregoing, the efficiency of energy storage will be a key aspect. At present, the technological transformation of batteries is under way, which is also demonstrated, among other things, by the increasing amount of FDI also appearing in Hungary.

In terms of the application of renewable energy resources, the largest energy producers include China, the United States, Brazil, Canada, India and Germany. Between 1995 and 2005 renewable energy resources were dominated by hydropower, but since 2010 the use of wind and solar energy has increased significantly. In 2016, within the utilised renewable energy sources, hydro-electric energy accounted for 75 percent, wind energy for 17 percent and solar energy for 6.1 percent (Chart 4-8). Today, the countries with the highest ratios of renewables within the total energy sources are India and China. In India, renewable energy resources account for almost 20 percent, while in China they make up 10 percent (IEA, 2019a).

However, the use of renewable natural assets is not only rising in the countries with the highest energy consumption, as substantial improvement can be observed also in developing states. For example in Brazil and Columbia (hydro-electric energy), Mexico (hydro and wind) and Kenya (hydro and geothermal energy) (REN21, 2019).

Chart 4-8: Share of the renewable energy resources in electricity production



Source: IEA.

By 2025, Copenhagen may become the world's first carbon-neutral city, operating entirely with electricity from renewable sources. In addition, Munich, in an initiative adopted in 2018, has set the target of establishing a district heating system based completely on renewable energy resources by 2040, which was also joined by Amsterdam, Helsingborg, Osnabruck and Vienna, while in the United Kingdom more than 80 towns plan to fully change over to renewable energy by 2050. The C40 initiative established in 2005 (which unites more than 90 cities) states that cities should take measures to build a healthier and more environmentally sustainable future, if the nation states and governments do not prove to be efficient enough. At the same time, C40 is also committed to implementing the goals of the 2016 Paris Agreement.

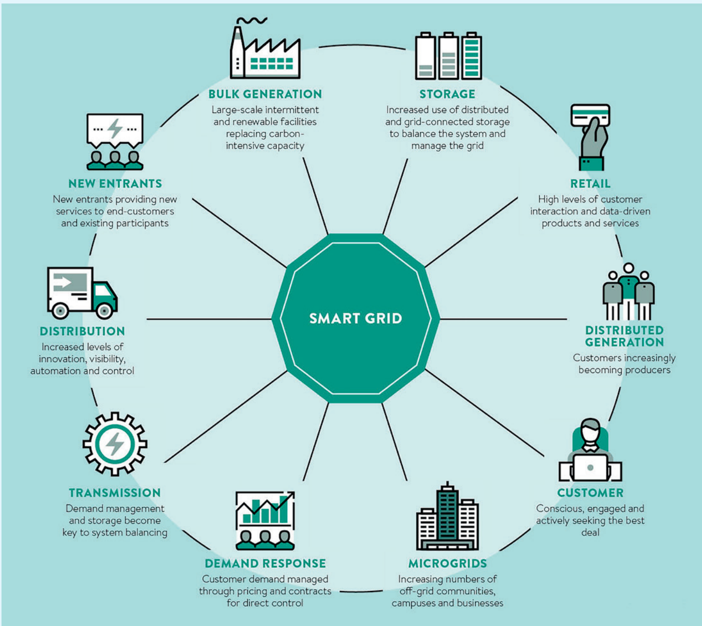
Based on the forecasts, with technological change and transition to green growth, **global energy intensity may fall by 36 percent by 2030**, which would occur in parallel with a decrease in CO_2 emissions. Due to energy conservation efforts, efficiency gains, and the higher rate of using renewable energy sources, according to the forecasts, over the long term the energy demand of the global economy may decline by 25–34 percent, which would be mostly **attributable to the decline in demand for fossil fuel. By 2050 renewable energy resources may account for 29–45 percent of total electricity production**, while the share of fossil fuels, particularly coal, falls to 34 percent (UNEP, 2011; McKinsey, 2019). Furthermore, according to the projections, lower energy consumption will generate annual average energy savings of USD 400-450 billion between 2010 and 2050 (UNEP, 2011; McKinsey, 2019).

However, in addition to the rise in energy efficiency, further growth in the role of renewable resources has several other impacts on industrial transformation. **The manufacture of solar panels and components for wind power plants will transform industrial structures, and the increasing automation and data-driven operation will also have a significant impact on employment in the energy sector.**

Box 4-2: Smart grid as the future of the energy sector

According to the definition used by the Office of Electricity (2019), a smart grid is an electric network **which collects information on the energy consumption habits of service providers and consumers relying on information and communication technology and adjusts accordingly to changes in energy supply and demand,** thereby reducing energy imports. Using this information can automatically increase the efficiency, reliability, economic efficiency, sustainability of the grids, and the predictability of the whole national economy's energy consumption also rises substantially (Chart 4-9).

Chart 4-9: Opportunities offered by the smart grid



Source: PWC.

With smart grid technology, grids become "smart" and flexible, as the energy network not only become more reliable, but also more efficient (facilitated by transmission lines equipped with sensors) and able to reduce weather consequences (e.g. in the case of storms). In such cases, the system automatically report power cuts, provides consumers with more accurate and proper information, automatically eliminates the faults and makes up for the lost power by sharing the surplus energy stored in batteries, which is aligned with consumers' needs and results in major savings (OE, 2019; smsplc, 2017). As regards e-vehicles, it becomes possible for the user to set automatic charging of the vehicle during the sunny hours, or programme the use of the washing machine or dishwasher depending on the energy demand related to operation and the energy price (smsplc, 2017).

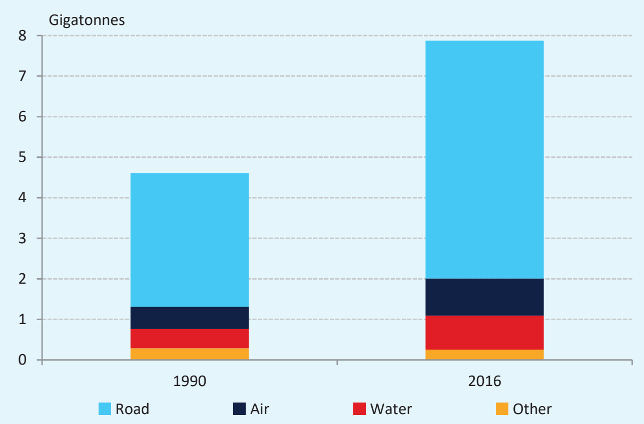
Relying on smart grids, users settle their energy consumption and costs in line with their demand, thereby curbing overconsumption, which ultimately increases their disposable income. Final consumers are conscious, committed and actively look for the best solutions (PWC, 2018). Public utility companies and service providers also benefit from the modernised grid, and owing to the continuous integration of renewable energy resources (primarily wind and solar energy), **grid overload decreases, and the modern technology provides higher security of supply and results in lower operating costs** (Munuera, 2019).

The EU's goal is to have at least 80 percent of traditional meters replaced by smart meters by 2020. However, by 2020 the share of smart meters is expected to amount only to 23 percent (European Commission, 2014). Based on Eurostat (2019) calculations, **deployment of smart meters and smart grids may reduce the European Union's CO_2 emissions**, as well as households' annual energy consumption **by 9 percent.** Consequently, the application of big data may provide a solution for improving energy diversity and the high quality provision of affordable electricity supply (Mordor Intelligence, 2019).

4.2.2 TRANSPORTATION SECTOR

The transportation sector has expanded significantly in past decades. Air passenger traffic has risen annually by 5-8 percent on average since 2010, making the largest contribution to growth. The primary reason for the growth is the rise in the market share of cheaper airlines, and improvements in the income position of the global middle class, particularly in China (Statista, 2019).

Chart 4-10: Global CO_2 emissions in the transportation sector, by sub-sector



Source: IEA.

As in the energy sector, the number of data sources and the volume of data is also rapidly increasing in the transportation sector. Sensors are used at more and more locations, for instance in air and sea ports, train and bus stations, logistic hubs and warehouses. As regards trucks, information related to loading and unloading time, travel times, driver hours, truck driver logs, pallets, transit and dwell times, strikes and other data are already available (Rusitschka and Curry, 2016). In Dublin, for example, **monitoring almost 1,000 buses every 20 seconds, data are forwarded on the bus timetable, detectors, closed circuit cameras and GPS updates.** Based on this, it is possible to prepare a digital map of the city, and thus by using the geographic information system data, real time data can be obtained on the position of the buses in the city. Owing to the results thus obtained, **travel times decreased by roughly 10-15 percent on the whole, which contributed to a reduction in CO_2 emissions**. In addition, optimising public transport and reducing emissions has helped to improve the condition of the environment. Furthermore, it managed to reduce – and in many cases terminate – underutilised lines, thereby also reducing the costs of the transport company (Tabbitt, 2014).

According to a proposal of the European Commission adopted in 2019, **starting from 2020** Member States – including Germany, as one of the largest European car manufacturing countries – **must reduce the CO_2 emissions of newly manufactured cars by 35 percent compared to the previous levels**. Pursuant to the regulation adopted earlier by the European Commission and the Council, by 2021 car manufacturers must reduce their fleet level CO_2 emissions to a defined health limit, to 95 gram/kilometre on average (European Parliament and the Council of the European Union, 2019).

Due to the negative impacts of pollutant emissions on human organism and the environment, **the idea of banning older diesel cars from driving into the cities has arisen in Germany and other European cities as well.** The first ban entered into force on 31 May 2018 in Hamburg. In Frankfurt, from February 2019 diesel cars complying with Euro 4 or older standards are prohibited from entering the city centre. Since March, the use of diesel cars was prohibited on certain road sections of Stuttgart even for local inhabitants. From summer 2019, no diesel engines with classification older than Euro 5 can be used in Cologne, Bonn, Gelsenkirchen and Essen. Since June 2019 traffic restrictions were introduced in Berlin for diesel cars meeting the Euro 1-5 standards (Kempken, 2019).

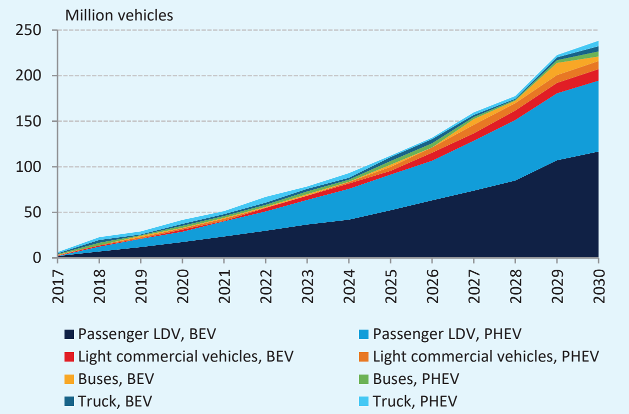
As a result of the foregoing, in the two countries that are most important in terms of the European car sales, i.e. **in Germany and the United Kingdom, diesel car sales have been on a declining trend from the second half of 2016.** In parallel with the change in the car mix, in Germany the ratio of newly registered petrol cars in Germany rose from 50 percent to almost 60 percent in two years, while the share of diesel cars fell from 50 percent to 35 percent. The change observed in the United Kingdom was even more distinct: the ratio of petrol cars rose from 50 percent over 65 percent, while that of diesel cars fell from 50 percent below 29 percent within new car registrations.

An increasing number of car manufacturers are starting to produce e-cars in order to comply with the requirements and to avoid high penalties.[17] However, according to a study by ADAC, the German automobile club, **if we consider all of the energy consumed over the entire lifecycle of a vehicle, gas- and hydrogen-powered cars may be more environmentally friendly than e-cars. This is partly due to the composition of the German energy mix, and partly to the high pollutant emissions of battery manufacturing.** E-cars prove to be more environmentally friendly than the hydrogen or natural gas vehicles only if the electricity used by them comes entirely from renewable energy sources (ADAC, 2019).

Over the next 5-10 years, e-vehicles may become more economical than the vehicles with internal combustion engines (McKinsey, 2019). Reykjavik is working on getting rid of carbon dioxide in its energy scheme, to ensure that its car traffic and public transport are fossil-free by 2040 (REN21, 2019). According to the plans of BMW, Mercedes and Volkswagen, from 2025 e-cars will account for 25 percent of their total sales, and they intend to introduce more than 100 new electric models to the market. In addition, in the area of alternative drive, Sunfire – with financing by Audi, Boeing and ThyssenKrupp Marine Systems – is also working on an industrial development that produces synthetic fuel, e-diesel, which is one alternative to replacing the fuels used for water and air transport.

Based on the calculations, by 2030 more than 130 million electric and more than 90 million hybrid electric vehicles may be registered for use. Within this, electric passenger cars will have the highest share (Chart 4-11).

Chart 4-11: Anticipated changes in the stock of e-vehicles between 2017 and 2030



Source: OECD/IEA, MNB calculation.

In cooperation with the Carbon Trust, British Telecom examined the CO_2 emissions resulting from the company's business activity. It came to the conclusion that **two thirds of the CO_2 emissions generated company operations stem from transportation.** By identifying the affected areas, the company had the opportunity to reduce costs and CO_2 emissions. **The company achieved this by also involving its suppliers in the reduction of CO_2 emissions. Since 2011,** the company has **achieved a 44 percent decrease in its CO_2 emissions from its operations and a 15 percent decrease in the CO_2 emissions of the supply chain**; it was also able to reduce other waste generating pollution by 40 percent (Nepal, 2014).

Since transportation is the largest emitter of carbon dioxide of all industries, all factors that are able to shorten, accelerate and optimise supply chains are of key importance. In his analysis, Bekker (2009) presents a company, which examined the route of its suppliers, weather conditions and traffic data, and then forecast the potential delays and elaborated an alternative plan to ensure that production never stops due to a shortage of material. Thus, it also reduced emissions of pollutants and its costs.

By 2050, green investments amounting to USD 150-400 billion will be implemented annually in the transportation sector, which is expected to improve efficiency; these investments will also facilitate a shift toward environmentally conscious transport. According to the forecasts, **by 2050 the proportion of rail and bus passengers may increase by 18-30 percent, while total passenger car traffic will decrease and over a horizon of 30 years and**

17 After 2021, German manufacturers may expect major penalties, which – according to preliminary calculations – would represent a material part of their 2018 pre-tax profit. If the trends continue, according to our calculations the penalty to be imposed on the Volkswagen group, Daimler and BMW would amount to 55 percent, 26.4 percent and 25.5 percent of their 2018 profit, respectively.

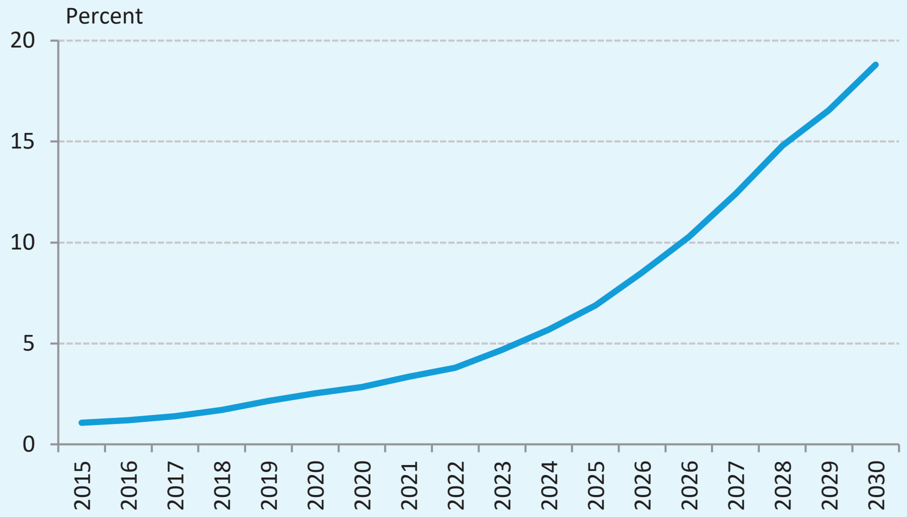
will account for only one third of total traffic. The penetration of new technologies, expected to take place in relation to all means of transport, will result in energy savings; **the energy consumption and CO_2 emissions of all vehicles will drop by 40-50 percent by 2050** (Tricoire, 2019).

Box 4-3: Impact of car sharing

The essence of car sharing is that the, **mostly electric, cars parked at various points in cities can be used by drivers after an internet-based registration and booking. This helps reduce not only the costs related to the maintenance of the vehicle** (since a registration and monthly fee must be paid for the service, and hourly and kilometre charge for the use, which also includes the price of the fuel), **but pollution as well.** This represents a novel, personalised form of public transport, which can be used at any time of the day and a car can also be used by more people (Economist, 2016). The advantage of car sharing is that there will be fewer car owners and accidents; furthermore, **it has a positive impact on reducing traffic and helps reduce parking needs, which results in lower carbon dioxide and pollutant emissions, and less environmental burdens** (Schreier et al., 2018).

In several countries, number of companies are offering car sharing services, which are becoming increasingly popular and spreading in the cities of the world, e.g. in Tokyo, Moscow, Beijing, cities of the United States and Europe, also including Budapest. Due to its relatively small innovation content, the impact of car sharing is often underestimated, and it is only regarded as a sub-market of driving, since even in the United States less than 1 percent of the total distance of car is accounted for by car sharing. According to the expectations of Morgan Stanley, **while the rate of car sharing on public roads is continuously increasing and may reach 20 percent by 2030**, the dynamics of vehicle manufacturing is gradually decreasing, primarily due to the environmentally conscious behaviour (Smith, 2016) (Chart 4-12).

Chart 4-12: Evolution of the global car sharing forecast



Note: Shared cars include taxi services, but do not include rental cars.
Source: Morgan Stanley.

According to calculations by Frost and Sullivan, a car owner can save USD 1,834 on average – assuming travel of 19,000 km annually – by switching to a car sharing service (Economist, 2010). **A survey of the car sharing system operating in Bremen showed than one shared vehicle is able to replace 14 privately owned cars.** Car sharing has also contributed to the change in households' car purchase decisions, as **they purchased 2,700 fewer vehicles. In**

addition, they also travelled less than an average Bremen household. Furthermore, car sharing users do their shopping more often locally, in Bremen, which also strengthens the local retail trade turnover. Moreover, car sharing users travelled 15-20 percent fewer kilometres than before they started to use this service (Schreier et al., 2018).

Nijland et al. (2015) obtained similar results using Dutch data, i.e. the households using car sharing travelled significantly less and the ratio of car owners is also lower. Thus, expansion of the **service reduced annual CO_2 emissions by approximately 250 kg**. In a breakdown by the means of travel, car sharing **replaced 38 percent of car use and 35 percent of travel by train.**

4.2.3 AGRICULTURE

While agriculture has the lowest global CO_2 emissions of the sectors under review, as a result of human activity, the ratio and quality of harvested and arable land are continuously decreasing and deteriorating. Due to the demographic boom observed in the developing countries, the shortages of food and the long-term social and economic damages resulting from this, the sector badly needs the latest technologies to mitigate and arrest these trends.

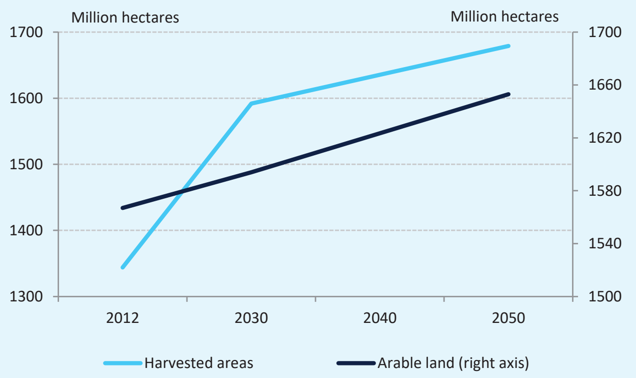
For this reason, green investments are also essential in agriculture (particularly in the developing countries). Due to the increasingly frequent extreme weather conditions, the issues of drought, flooding, deforestation and food waste are receiving stronger emphasis, as they substantially influence access to food and nutrition, and accordingly, production and processing as well. The rapid, continuous increase in fossil fuel-based energy consumption and the growing exploitation of natural assets represent a risk to the food, drinking water and wood supply, as well as the fish population (WBCSD, 2010).

The Netherlands and Denmark, serving as an example for many countries, committed themselves to sustainable agriculture in the early 2000s. As a result of this, the technological maturity of the aforementioned countries is almost unique in agriculture. **They already use drones to monitor arable land** in many places, **and thus the chemistry and water content of the soil can be examined from a height of 10 meters. In addition, farmers obtain information about the degree of the nutrients in the plants, and due to this they can also easily assess the progress of growing.** Relying on a mobile phone application, the soil PH, organic material content and other characteristics can be tested. Using these results, additional analyses can be produced in a short time. Since 2000, some of the plant breeders reduced the water dependency of the plants of key importance for the country by 90 percent. In addition, producers in several cases entirely eliminated the use of pesticides. **Progress was also achieved in animal husbandry, as Dutch poultry and livestock farmers have managed to decrease the use of antibiotics by 60 percent since 2009** (Viviano, 2017).

Furthermore, big data may facilitate the forecasting of food shortages by combining information related to drought, weather conditions, migration, prices and earlier production data (Hammer et al., 2017). In connection with this, the US-based firm **Climate Corporation provides weather simulation to farmers and producers which prepares estimates and forecast of the expected crop yields based on the daily weather data over the past months.** (It collects information from approximately 2.5 million locations and also performs soil observation.) Thus, farmers and producers can plan planting and harvesting better and more efficiently (Lokanathan et al., 2017).

As scarce resource, drinking water requires continuous monitoring. There are number of examples in this field, where early intervention is possible **relying on data from measuring instruments installed in industrial network, from the water-purifying plants and the test equipment.** In this way they contribute to reducing the spread of illnesses related to pollutants in the water, and the technology may also help public utility companies and industrial users comply with water quality requirements.

Chart 4-13: Forecast for harvested and arable land based on the green growth scenario



Source: FAO, MNB calculation.

The intensity of agricultural production is likely to rise in parallel with the increase in population, which is also confirmed by the forecasts. Based on these projections, **the area under agricultural cultivation is expected to rise to 5.4 billion hectares by 2050, while grass and arable land between 2010 and 2050 are expected to increase by 11 and 6 percent, respectively, if the examined technological change is realised.** The harvested area is expected to reach 1.7 billion hectares to meet the increasing food demand (Chart 4-13). The annual value of agricultural investments may reach USD 120-200 billion on average, which may primarily be used for agricultural research and development, pest control and food processing. In the field of plant cultivation, **crop yields are expected to increase by 11–17 percent by 2050.** According to the expectations, by 2050 soil quality will improve by 21-27 percent, which is attributable to the delayed effect of more sustainable agricultural practices and technologies (UNEP, 2011; FAO, 2018).

4.2.4 MANUFACTURING

The high level of CO_2 emissions by the manufacturing sector (see Section 2) clearly illustrates the need to implement green technologies that boost efficiency and environmental sustainability, in conjunction with energy- and material-efficient production processes, which on the whole results in decreasing pollutions and costs (UNEP, 2011). According to Tricoire (2019), green manufacturing is primarily about changing the business and productions practices, and the attitude of the companies, as well as about the electrification and digitalisation of processes. In addition, it is also essential to replace carbon intensive materials with less carbon intensive, natural materials. Cleaner and safer industrial production and green manufacturing have a significant impact not only on the environment, but also on human health.

According to Tricoire (2019), it is essential to enhance the material processing systems. For example, the application of wheat straw packaging may result in 40 percent energy saving and 90 percent water saving. **Saint-Gobain** is a good example of this, **which wants to reduce its CO_2 emissions in production by 20 percent by 2025 via digital innovation and curbing energy consumption** (Dhalla, 2019).

According to Tricoire (2019), within the production process, in addition to maintenance, repair and renovation, reuse and recycling also gain importance in the optimal use of resources. **Whirlpool, for instance, applies enhanced recycling practices during the production process, by collecting cardboard boxes and plastic, which serve as raw material for parts in production. The company expects to save almost USD 3 million using this method** (Whirlpool, 2019).

Owing to the production process innovation, the improved efficiency realised in the energy-intensive industries also helps to protect the environment. **By enhancing its production processes, the pharmaceutical company Bio-pharma reduced the error factor of its end-product and cut its operating expenses by 13 percent, which also had favourable impact on the volume of consumed energy.** Using the available data which was not previously used in process optimisation, they defined the key factors influencing the end-product, which helped them change the quality and cost of the end-product (Msrcosmos, 2017).

New technologies (such as artificial intelligence, business intelligence and cloud computing) being deployed by manufacturing optimise and flexibly steer the use of renewable energy resources. According to the expectations, by 2022 almost 75 percent of manufacturers will use cloud computing services, which may help to substantially reduce environmental burdens (Dhalla, 2019).

4.2.5 SERVICES SECTOR

Similarly to the developments that are currently underway, in the near future the weight of the tertiary sector is expected increase further, which will also boost environmental sustainability. More and more services are available – also in the sectors we have highlighted, such as healthcare and financial services – that rely on the use of big data, which increasingly puts the focus on the environmentally friendly, efficient utilisation of resources. Due to the development of technology and big data, employment in the services sector can be expected to increase in long term.

The future of the services sector will be determined by the implementation of certain key technologies and the speed of their penetration. One of the most important of these is FinTech (Financial Technology), which compared to traditional financial service providers (e.g. banks), uses the latest technologies to offer innovative financial services, providing a superior customer experience. The key areas of the application of Fintech (money transfer, payments, consultancy, banking, etc.) may fundamentally alter the current form of the financial sector.

Another technology of great significance is blockchain. "Blockchain is the incorruptible digital general ledger of economic transactions, which can be programmed not only for the recording of financial transactions, but virtually for anything that has a value."[18] Its mechanism based on decentralisation makes the application safe, and thus it may represent the future in areas such as smart contracts (coding of simple contracts, which are executed when the defined conditions are fulfilled), the sharing economy, community financing, data storage, the Internet of Things, management of personal data, share trading, etc.

Finally, looking ahead, **the development of artificial intelligence will also have significant impact on the development of services.** AI-based solutions are fundamentally transforming the current conditions in transport (spread of autonomous cars), education, healthcare (personalised medicine recommendations, 24/7 health consultancy), retail trade (personalised offers, efficient comparison of various offers), banking (fast and accurate loan administration, curbing fraud) and will raise the customer experience to a completely new level in the near future.

4.2.5.1 Healthcare

Due to the new and smart technologies and forecasts, healthcare expenditures are expected to decrease and this may help improve the health condition of the society, which may result in further savings, and it may be possible to reduce and prevent epidemics and other diseases.

In 2014, Beijing concluded a 10-year agreement with IBM and Green Horizon, based on which they developed an advanced weather forecasting system relying on cloud technology, artificial intelligence and IoT, to resolve the smog problem. **The city created an early warning system by setting up 35 observation stations, which can forecast the degree of acute pollution three days in advance, using the incoming data (traffic levels, weather, humidity, wind patterns, etc.).** In addition to this, China intends to reduce CO_2 emissions by curbing carbon-based energy production, optimising the cloud-based analytical system and applying renewable energy resources (Nepal, 2014). **As a result of this, Beijing was able to reduce the ratio of ultrafine particles (i.e. aerosol, smoke, dust, ashes and pollen) in the air by 20 percent,** and thus it came closer to its objective set in 2017, to achieve a reduction of 25 percent (Theron-Ord, 2015).

Digitisation also has significant potential in other areas of health services. Telemedicine allows a patient to consult with a doctor who is in another part of the world, thus reducing treatment time and costs. In addition, the development of Artificial Intelligence may also reduce the duration of assessment. After an MRI scan is complete, the computers will immediately establish a diagnosis and outline the further course of treatment. Finally, portable smart devices (smart watches, smart bracelets) immediately and automatically notify emergency services, thus increasing the chances of survival.

4.2.5.2 Financial services

The Paris Agreement adopted in 2015 also includes curbing global CO_2 emissions of financial processes, and the UN also joined the initiative with an SGD target. The agreement emphasises investments in sustainable technologies and corporations (encouraging lending for environmental purposes), which may finance growth in a sustainable, long-term manner, and can contribute to low CO_2 emissions and protecting our environment (European Commission, 2019a). The mobilisation of private investors is essential in the financial sector as well, for the global financing of sustainable projects (combating climate change, social inequalities, exploitation of natural assets) (European Commission, 2019b). **Pursuant to an agreement signed in 2019, the Dutch Tridos Bank committed to reducing its CO_2 emissions by 49 percent until 2030 by financing sustainable projects (primarily renewable energy source projects) such as wind and solar energy park investments** (van Waveren, 2019).

Banks and insurers have direct and full access to a large amount of customers' financial data. In addition to customer data, they also collect data from social media, mobile phone data and other surveys, which may facilitate customer retention, offers and faster data processing (Hussain – Prieto,

18 Don & Alex Tapscott, authors of Blockchain Revolution (2016).

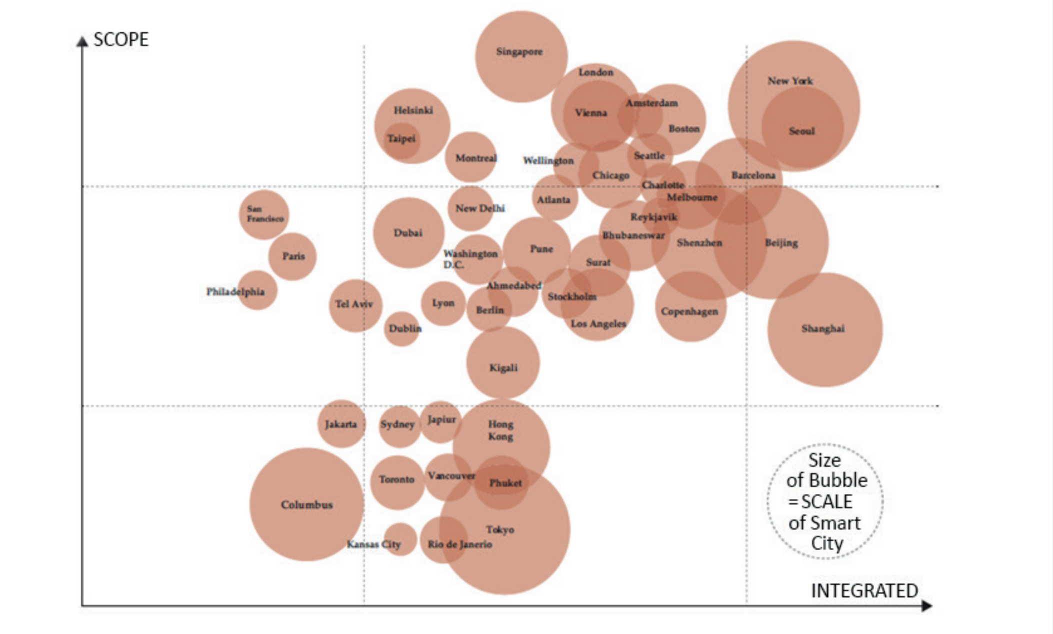
2016; Simplilearn, 2019). The latest technological accomplishments can be used in the insurance sector as well. **Insurers collect data via sensors and send drones to disaster areas (such as after the Katrina hurricane) or to other locations which are difficult to approach. Due to this, the processing time of the assessment became shorter and injured people access the insurance amount faster** (Economist, 2019b). Based on the surveys by Dlugolecki – Lafeld (2005), climate change may increase potential property loss by 2-4 percent annually. 35-40 percent of the losses occur as a result of natural disasters, more than three quarters of which are caused by storms and floods. Climate change may further exacerbate the intensity of storms, increase the greenhouse effect and lead to a further rise in temperatures.

Box 4-4: Smart cities as the most efficient response to urbanisation

In recent decades, increasing urbanisation has been observed globally, but particularly in the developing countries. **In 2018, 55 percent of the world's population lived in cities, and based on the forecasts this proportion is likely to rise to 68 percent by 2050.** Further increases in the rate of urban population will cause urban conditions to deteriorate, and it is essential to ensure that cities operate in a sustainable way, both in environmental and economic terms (UN, 2019). Although based on the data of WHO, cities are the growth engine of the economy – almost 80 percent of global GDP is generated there – all of this is coupled with an extreme degree of CO_2 emissions (75 percent of the world's CO_2 emission is generated in cities).

A smart city is **a city that uses the available technological opportunities in an innovative way.** In addition, it promotes better development and a "more intelligent", more sustainable and more efficient urban environment, i.e. it results in sustainable and responsible economic development, which increases the standards of living (Lados – Horváthné Barsi, 2011).

Chart 4-14: Development and integration level of the world's smart cities



Source: Eden Strategy Institute and ONG&ONG Pte Ltd.

In the city of Songdo, the **primary target was to achieve low CO_2 emissions, and the energy efficient, environmentally sustainable expansion of the city by applying state-of-the-art technologies.** Several multinational technological companies joined forces with the local authorities to create the city, where developed information and communication networks are applied. All buildings form a shared information system, thus their operation is more cost efficient, and it is also possible to set remotely the temperature, lighting conditions of the homes and buildings and etc., allowing energy consumption to be monitored continuously. This results in optimal, lower energy utilisation, for which wind and solar energy is also used. **Sensors, detectors and chips collect data (e.g. on traffic condition) for the operation of the city, which are processed and analysed by a central system.** One example of this is the system of street and traffic lights, which operate depending on the waiting pedestrians and vehicles, thereby also saving energy (Czirják – Gere, 2016). Another prominent example is the city of Barcelona, which makes a large amount of investments in IoT applications. Through the interconnectedness of the devices, the city collects a huge volume of data, used for controlling its daily decisions. **The city realised energy savings of 30 percent by operating LED lights equipped with sensors at specific traffic points, which shine only if they detect motion. Furthermore, these sensors also collect data on noise levels, air pollution and humidity.** Due to the IoT applications, Barcelona saved water worth almost USD 58 million. **The city management hopes that with these measures it will be able to reduce costs and increase social welfare, by using the resources and available data more efficiently.**

According to the plans, Copenhagen may become entirely green, smart and carbon-neutral city as early as 2025. The goal is to reduce heating and commercial electricity consumption by 20 percent, and to achieve that 75 percent of transportation is by bicycle, on foot or public transport. Furthermore, it intends to install 60,000 square meters of new solar panels and to achieve that the city's heating need is completely satisfied by renewable energy. By 2018, Copenhagen's heating consumption was reduced by 15 percent, 66 percent of travel already occurs in the city by bicycle, on foot or by public transport, and 51 percent of the heating and electricity come from renewable energy sources. Due to the technologies and infrastructures developed until now in the city, **the city's CO_2 emissions fell by 42 percent since 2005, although challenges related to mobility and energy consumption still exist and need to be addressed to achieve the goals by 2025. The green transformation of the capital of Denmark may contribute to creating green jobs and to economic growth, which may result in higher standard of living** (Robertson, 2019).

Amsterdam is cooperating with more than 100 partners in the implementation of innovative projects. Practically, a social interface covers the entire ecosystem, where, among other things, issues and requirements may be raised and information related to events and solutions may be obtained through posts. The created solutions include: integrated reporting for the population (accident, fire, crime, etc.); e-charging station network; innovative green energy utilisation solutions; smart public lighting on cycle tracks (switches on when it detects motion, powered by wind and solar energy); green roofs; virtual power station project (storage, "trading" of renewable energy among users to improve capacity utilisation); energy atlas (to promote the use of renewable energy) (Czirják – Gere, 2016).

In Singapore, the SkillsFuture programme facilities the development of digital capabilities among the urban population. The Tech Skills Accelerator programme trained more than 27,000 people in the area of data analysis, artificial intelligence and big data (Eden Strategy Institute and ONG&ONG Pte Ltd., 2018).

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5 Impact of digitalisation and technological progress on prices

The world is continuously changing, at an ever increasing pace. These changes simultaneously represent new opportunities and challenges for all economic agents. Megatrends, such as digitalisation, technological progress and automation have a significant impact on the functioning of the global economy and on our everyday life, to which we need to adapt day by day, as in the age of digitalisation and internet the traditional functioning of the market changes and the interrelation of economic agents undergoes transformation.

The expansion of the digital world and the large volume of data it generates represent new challenges for economists, policymakers and statistical offices wishing to understand economic trends. The data revolution is accelerating the growth and generation of the volume of data, extends the range of phenomena that can be analysed and presented by data, facilitates increasingly faster availability of data, expands the range of data sources and increases the number of data producers, processors and analysts. These changes encourage statistical offices to modernise traditional measurement methods and integrate the secondary data source represented by big data as much as possible.

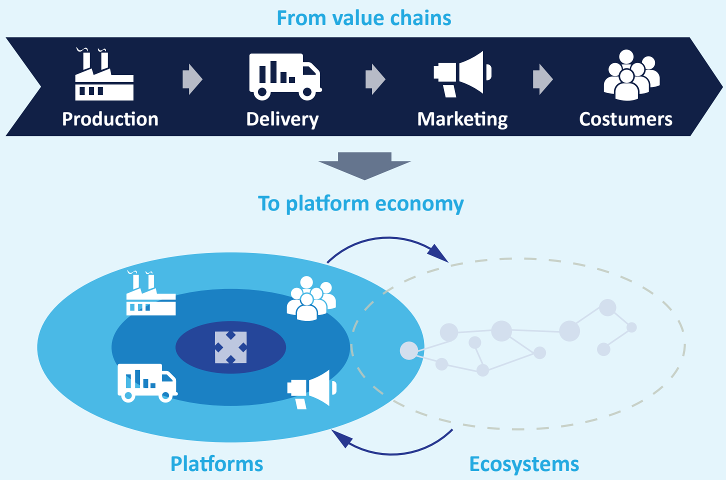
The impact of digitalisation and technological progress appears in corporate strategies and pricing decisions, and thus also in inflation. There are four main channels through which the internet and digitalisation exert an inflationary impact, i.e. e-commerce; more conscious, better informed consumers; automation; and IT development (ICT tools). The result of these points to lower inflation. Quantum pricing, as a new pricing strategy, also represents a challenge for official statistics, which primarily raises issues of the representativeness and predictability of price changes. These are the new challenges faced by the traditional measurement methodology, which should see these changes as a new opportunity.

5.1 Impact of digitalisation on our daily life

The surrounding world is continuously changing, at an ever increasing pace. Megatrends, such as digitalisation, technological progress and automation have a significant impact on the functioning of the global economy and on our everyday life, to which we need to adjust day by day. These changes simultaneously represent new opportunities and challenges for all economic agents. As a result of digitalisation and the increasing use of the internet, consumer behaviour with products and services changes (online shopping) and consumer awareness rises. Digitalisation has revolutionised the use of media, financial and public services, communication with each other, etc. From the perspective of companies, today's digitalisation technologies, such as mobile technology, big data, cloud storage, sensors, digital platforms and automation may bring about a remarkable transformation in the traditional operation of companies, and the way firms cooperate with their suppliers and serve consumers.

The internet is penetrating to a significant and accelerating degree, as was already presented in Section 4. All of this has laid the foundation for the operation of **platform economies**, which **change the traditional functioning of the market and the interrelation of the actors, and indirectly also corporate strategies and pricing.** The transformation represented by digital platforms and clouds is also referred to as the third globalisation, marking the start of a new phase in the globalisation process (Kenney–Zysman 2016). To make a comparison, we can say that while the first industrial revolution was organised around factories, the transformation taking place today is organised, in a broader sense, around digital platforms. The **platform economy – or digital platform economy – is a collective term for digital companies operating on the internet, which conduct a variety of business, social and other activities.** Amazon, Uber, Facebook, Google and Alibaba are revolutionising their own functional area by connecting demand (consumers) and supply (producers) in a manner that differs from the traditional way. On most platforms, we can execute some sort of transaction, but there are also innovation platforms, e.g. the innovation platform of Microsoft, which provides access for users and independent developers to a variety of technologies. Chart 5-1 presents the operational principle of the platform economy.

Chart 5-1: Operational principle of the platform economy



Source: Grow VC Group.

In the platform economy, we can identify the elements of network operation, e.g. the more users join the platform, the more efficiently the platform can work and the benefit of its actors rises to an increasing degree. In addition to the "traditional" actors of the platform economy, ecosystems also appear, which create value within a platform in a way that in fact their operation is regulated not by the owner of the platform. These include, for instance, the actors that develop applications for the company operating on the business model of the respective platform. **The spread of the platform economy may also be observed among the largest companies of the world, since in 2018, 7 of the world's 10 largest companies operated on a platform business model** (Chart 5-2). Based on market capitalisation, two thirds of the world's 60 largest companies operating on platform business model operate in the USA, 30 percent of them are in Asia and a small ratio of them are in Europe. The largest US platform companies include Apple, Amazon, Microsoft, Facebook, Alphabet, Netflix, Paypal and Ebay. Among the largest Asian companies, Alibaba, Tencent and Samsung have the largest market capitalisation based on 2018 data.[19]

Chart 5-2: Top 10 global companies (2008 vs. 2018)

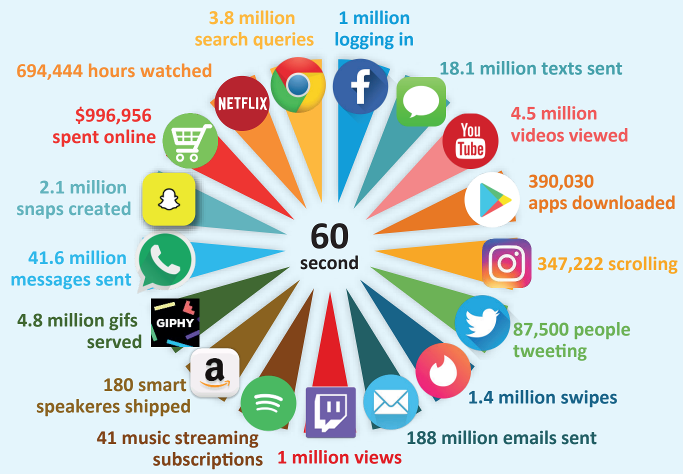
2008				2018			
Rank	Company	Founded	Billion USD	Rank	Company	Founded	Billion USD
1.	PetroChina	1999	728	1.		1976	890
2.	Exxon	1870	492	2.	Google	1998	768
3.	GE	1892	358	3.	Microsoft	1975	680
4.	中国移动 China Mobile	1997	344	4.	amazon	1994	592
5.	ICBC	1984	336	5.	f	2004	545
6.	GAZPROM	1989	332	6.	Tencent 腾讯	1998	526
7.	Microsoft	1975	313	7.	Berkshire Hathaway	1955	496
8.		1907	266	8.	Alibaba.com	1999	488
9.	SINOPEC	2000	257	9.	Johnson & Johnson	1886	380
10.	AT&T	1885	238	10.	J.P.Morgan	1871	375

Note: The red background denotes companies operating on a platform business model.
Source: Bloomberg, Google.

19 https://www.netzoekonom.de/2018/06/24/wert-der-plattform-oekonomie-steigt-im-ersten-halbjahr-um-1-billion-dollar/

All of us form part of the digital world and the digital society. The devices surrounding us, such as mobile phones, computers, tablets and smart watches provide us with access to the internet at any time of the day. As a result of this, **just in one minute unbelievably large volume of data are generated globally**, as we send vast number of e-mails, look for information, watch videos or shop online (Chart 5-3). This also continuously alters the measurement scale of the data traffic, and today data volume is already defined in exa-, zetta- and yottabytes (10^{18}, 10^{21} and 10^{24} byte). **The continuously growing volume of data poses challenges for economic agents dealing with the data.**

Chart 5-3: Events of one internet minute in 2019



Source: VisualCapitalist.

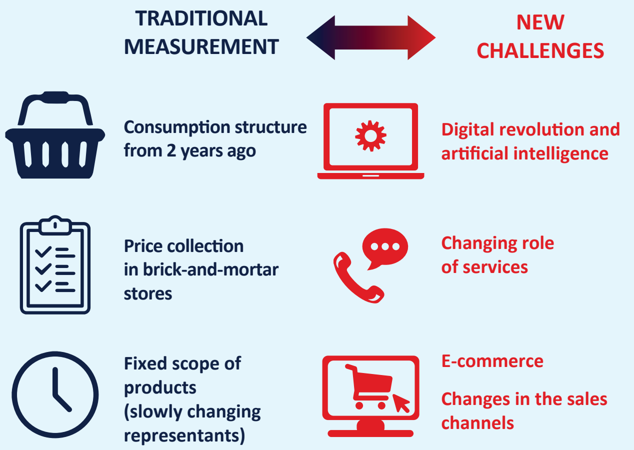
5.2 Impact of digitalisation on traditional statistics

Expansion of the digital world and the large volume of data it generates represent new challenges for economists, policy-makers and statistical offices wishing to understand economic trends. In addition to the previously used official data service, big data represents a secondary data source for strategic decisions. In terms of its volume, a significant amount of data is available and generated minute by minute, thereby causing a true data revolution in the age of digitalisation. Those who deal with data are all experiencing the sudden change represented by the data revolution, of which five different aspects should be highlighted. According to the UN's 2013 report, the data revolution

1. Accelerates the growth in the volume of data and the generation of data,
2. Expands the range of phenomena examinable and presentable by data,
3. Facilitates the availability of data faster and faster,
4. Expands the range of data sources, and
5. Increases the number data producers, processors and analysts.

These changes encourage statistical offices to modernise traditional measurement methods and integrate the secondary data source represented by big data as much as possible. This **may play an important role in making official statistics more precise, particularly in the measurement of price changes and inflation.** A digital revolution is currently taking place, in which big data and artificial intelligence are becoming increasingly important. **The role of services has appreciated remarkably in recent decades**, as they became increasingly important both for economic growth and price developments. **E-commerce and online shopping are also consequences of the digital world**, which are not only shaping consumer habits day by day, but are also transforming traditional sales channels. These are the new challenges faced by traditional measurement, which should see these changes as a new opportunity (Chart 5-4).

Chart 5-4: New challenges to traditional measurement in the 21st century



Source: MNB compilation.

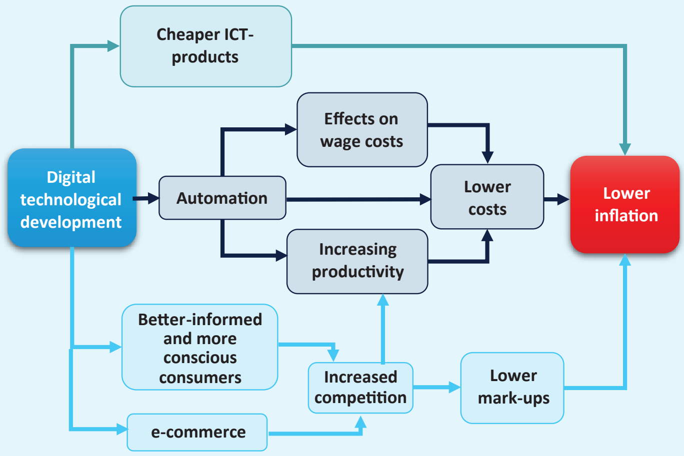
5.3 Impact of digitalisation and technological progress on inflation

The impact of digitalisation and technological progress appears in corporate strategies and pricing decisions, and thus also in inflation. Recently, analysis of the impacts of digitalisation on inflation has become increasingly popular in the literature, but the studies usually analyse the relationship in a qualitative manner, since there is a limited volume of data for quantitative analysis. Looking ahead, however, in the age of data revolution this will presumably change, as soon as the integration of big data in traditional measurement methods succeeds. One common feature of the studies is that, on a theoretical basis, they assume that technological progress essentially points to a decrease in prices. At the same time, the consensus of analysts is divided on the results: according to Riksbank (2015), Coffinet–Perillaud (2017), and Goolsbee–Klenow (2018), digitalisation and technological innovations have resulted and continue to result in a decrease in inflation. By contrast, ECB (2015), Cavallo–Rigobion (2016) and Cavallo (2017) argue that although in theory digitalisation represents a downside risk to inflation, the uncertainty of the quantitative results do not (yet) confirm this statement.

There are four main channels through which the internet and digitalisation exert their inflationary impact (Chart 5-5):

1. e-commerce,
2. more conscious, better informed consumers,
3. automation, and
4. IT development (ICT tools).

Chart 5-5: Main inflationary channels of the internet and digitalisation



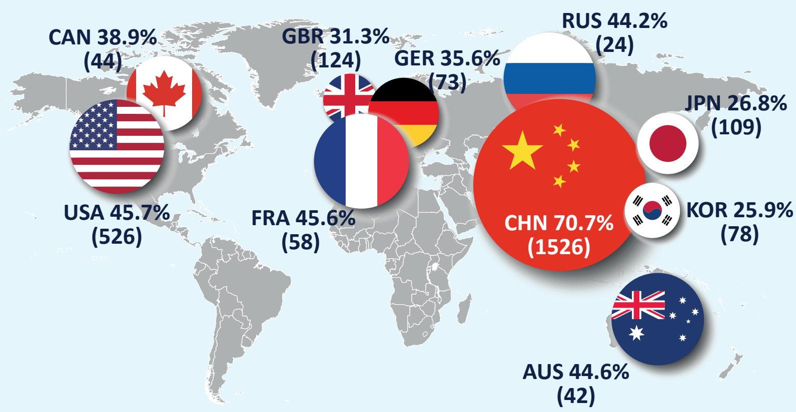
Source: MNB compilation.

5.3.1 E-COMMERCE

E-commerce – which is difficult to set apart from globalisation – **mostly reduces prices by increasing competition among firms and changing the traditional business model** (Poloz, 2017). The penetration of e-commerce creates new markets and expands consumers' options. According to ECB (2015) and Riksbank (2015), compared to the traditional sales channels, online selling can substantially reduce both retail and wholesale costs, and thus prices as well.

In the area of global e-commerce, China and the USA are in the lead, and looking ahead it is also these countries where the strongest growth can be expected in the coming years (Chart 5-6). In addition to e-commerce, m-commerce, i.e. mobile commerce, may also spread significantly, since today there are more and more applications which facilitate online shopping in a variety of product categories, and thus the ratio of m-commerce within e-commerce is continuously rising.

Chart 5-6: Anticipated growth in global e-commerce (2018–2023)

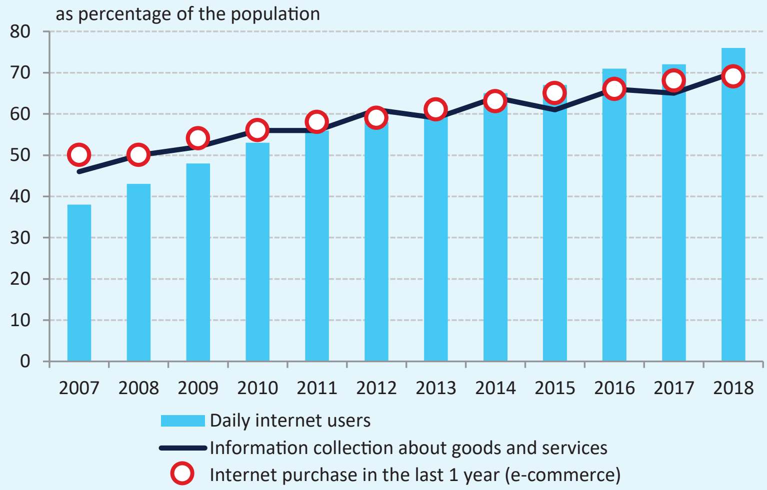


Note: In brackets the value of 2018 e-commerce in USD billions.
Source: Emarketer, Statista.

5.3.2 MORE CONSCIOUS, BETTER INFORMED CONSUMERS

As a result of digital technological progress and the increasing use of the internet, consumers are more and more aware and well-informed about price developments, since they immediately obtain information on the products or services they look for. This process is also supported by the statistics on internet usage in the countries of the European Union, since the ratio of **daily internet users** and those obtaining information on goods and services on the internet **almost doubled compared to 2007** (Chart 5-7).

Chart 5-7: Internet usage statistics in the EU-28 countries



Source: Eurostat.

As a result of the increasing internet usage, the consumption of products and services becomes "real time", which contributes to the continuous change in consumer attitudes today and in the future. It is difficult to separate the rise in consumer awareness from the expansion of e-commerce, one example of which is the phenomenon known as the Amazon effect. The essence of the phenomenon is that today purchases can be made anywhere at any time: one merely needs a device suitable for internet usage (e.g. smart phone). The consumer can check and compare the price of the products in a matter of seconds using a smart phone when in the shop, considering a purchase. During the (learning) process, consumers become increasingly aware, while companies face stronger competition and decreasing bargaining power. **It is typical of internet users that the more experienced ones treat e-commerce or m-commerce as an alternate to traditional sales**, while those less versed in the world of internet tend to use it to collect information; i.e. obtain information before buying a product in the shop or use a service (Coffinet–Perillaud, 2017).

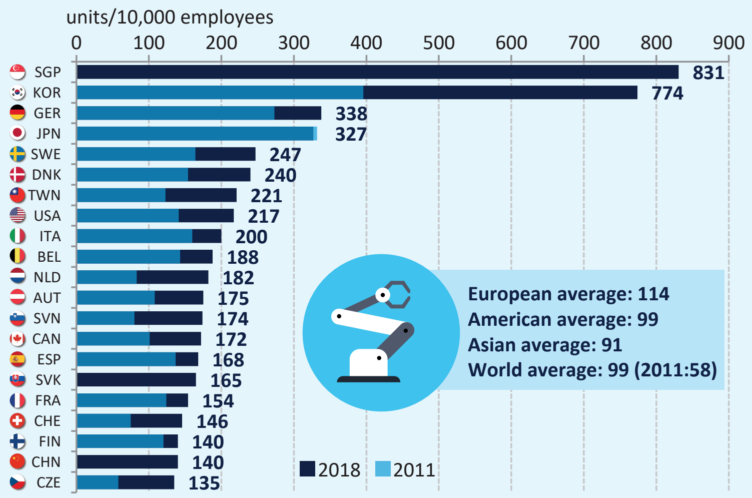
5.3.3 AUTOMATION

Automation is an important inflation channel of digitalisation and technological innovation. When talking about automation, the labour market effects caused by the technological revolution – measurement of which is extremely difficult at present – should not be ignored.[20] **Robotisation, the increasing complexity of production processes and the expansion of artificial intelligence change the operation of companies and transform the production chains.** In recent years, the number of robots used in industrial production rose substantially, and according to the latest forecasts, if the current trends continue, by 2022 the number of industrial robots across the world may approximate 4 million, i.e. the present volume almost doubles (IFR, 2019). **Globally, the distribution of industrial robots is the highest in Singapore, exceeding the European average almost 7 times and the Asian one roughly 10 times** (Chart 5-8). Compared to 2011, there was a significant – in certain cases twofold – growth in the number of industrial robots in all countries. The development and spread of robots is partly attributable to the fact that at present the computing capacity of computers has increased to such a degree that robots today are able to perform also non-routine work processes in full or in part.

20 For more details on the topic see Section 3 of the 2017 Growth Report.

According to Ray Kurzweil, American inventor and futurist – working on the development of machine intelligence since 2012 as director of Google's designer-engineering team – **technological innovations come about extremely rapidly in the world surrounding us**: just think about the penetration of digital equipment or the emergence of robots. According to his visions for the next years and decades, this technological progress increases day by day and we will witness unprecedented changes: artificial intelligence or virtual reality will be natural and it will be possible to map the functioning of human brain on super computers (Kurzweil, 2005).

Chart 5-8: Industrial robots per 10,000 employees in manufacturing, 2011 and 2018



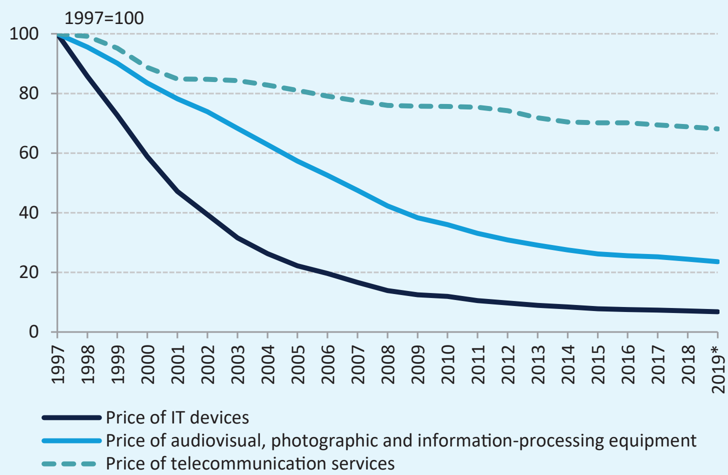
Note: No 2011 data are available for Singapore, Slovakia and China.
Source: IFR World Robotics 2013, 2019.

Automation and robotisation boost the efficiency and productivity of the labour force on the supply side. By default, growth in productivity entails a rise in wages: in parallel with the production process becoming more efficient, companies will have the opportunity to reduce the marginal cost of production, part of which – in addition to increasing profit – may also appear in the lowering of consumer prices. **On the demand side, automation leads to the polarisation of income.** However, consumption does not expand substantially in parallel with the rise in the share of higher income groups, since these households add this surplus income to their savings, and therefore the impact on inflation is less straightforward on the demand side.

5.3.4 IT DEVELOPMENT (ICT TOOLS)

Information and communication technologies (ICTs) reflect the indirect effects of digitalisation on inflation. Charbonneau et al. (2017) emphasise that the price of goods related to ICTs has been rapidly decreasing since the 1990s, while at the same time the appearance of new products and services, and the customisation and qualitative changes have generated challenges for statistical offices. **The exponential decrease in the prices of products and services linked to ICTs in recent decade(s) directly reduce inflation**, and second-round effects may also emerge, such as the integration of products with increasingly high digital content into production processes (Industry 4.0), thereby increasing efficiency and cutting costs. The products most affected by digitalisation include IT devices, audiovisual, photographic and information-processing equipment. However, the largest fall was observed in the prices of IT devices over the past two decades (Chart 5-9).

Chart 5-9: Changes in the prices of products and services affected the most by digitalisation in the EU



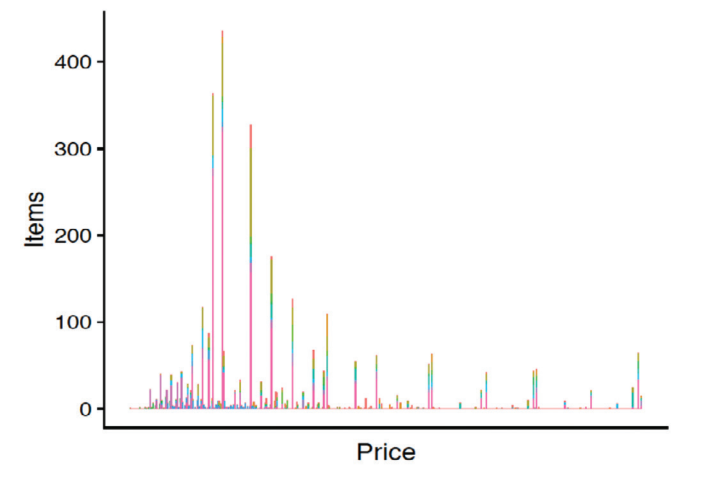
*Note: *Data are available up to October 2019.*
Source: Eurostat, MNB.

In connection with ICT tools, Kurzweil (2005) highlights the fact that in parallel with the price decrease the quality of IT equipment increases exponentially, i.e. the computing capacity per one dollar has increased at an accelerating rate. He emphasises that while in 1968 for 1 dollar only 1 transistor could be purchased, almost four decades later, in 2002, for the same price we could get 10 million transistors. According to his forecast, the computing capacity of (super)computers has now exceeded the capacity of the human brain, and if this trend continues, by 2060 the combined computing capacity of mankind will also lag behind that of the computers, while costs – including the prices of IT equipment – continuously decline.

5.3.5 QUANTUM PRICING AS A NEW PRICING STRATEGY

In the world of big data and data revolution, quantum pricing as a new pricing strategy also represents a challenge for official statistics. Quantum pricing, as a concept, is relatively new and has only recently become a focus of research. The notion first appears in the research of Aparicio (2018) and refers to the practice **that larger shops or chains, selling several hundreds or thousands of products, do not apply an individual price to each product, but rather define price categories.** The name comes from physics, since the properties of subatomic particles (quantum) belong to discreet categories rather than being distributed on a continuous scale. Shops define the price categories at relatively large, but in economic terms carefully considered distances from each other. Aparicio (2018) provides interesting examples to illustrate quantum pricing in practice: McDonald's offers 25 types of hamburgers in total at 20 prices, while Uniqlo, the Japanese clothing chain applies for 4,000 different products the same number of price categories. The clustering of prices can be observed at other clothing shops as well (Chart 5-10). **The quantum pricing strategy may typically be relevant for chains and product categories that are relatively homogenous, such as clothing, shoes or food.**

Chart 5-10: Clustering in the prices of Ralph Lauren clothing



Source: Aparicio (2018).

Quantum pricing represents a challenge for official statistics, because the clustering in prices raises representativeness issues. In small samples, the distribution of prices by categories cannot be confirmed, and thus a much larger sample size than the traditionally applied size is needed to ensure proper representativeness. Furthermore, it also arises, both in statistical and analytical terms, that upon repricing, when the typical categories of the shops are known, **price changes in the future will become much more predictable,** since the repricing will take place by reallocation from one price category to another one. As a result of this, looking ahead, the standard deviation of inflation may decrease, while its persistence rises, which is advantageous in terms of statistics and forecasting.

5.4 Summary

The surrounding world is continuously changing, at an ever increasing pace. Megatrends, such as digitalisation, technological progress and automation have a significant impact on the functioning of the global economy and on our everyday life, to which we need to adapt day by day. In the age of digitalisation and internet, the traditional functioning of the market changes and the interrelation of economic agents also undergoes a transformation.

The exponential growth of the digital world and the huge volume of data thus generated are now leading to a data revolution. This data revolution accelerates the growth and generation of the volume of data; extends the range of phenomena that can be analysed and presented by data; facilitates increasingly faster availability of data; expands the range of data sources and increases the number of data producers, processors and analysts. These changes encourage statistical offices to modernise traditional measurement methods and integrate the secondary data source represented by big data as much as possible**.** Digitalisation and the age of information also entail measurement difficulties, which was addressed in more detail in Section 3 of the 2017 Growth Report.

The impacts of big data and the data revolution mostly affect products and services connected to digitalisation. The impact of digitalisation filters down to prices through four main channels, i.e. e-commerce; more conscious, better informed consumers; automation, and IT development (ICT tools). The result of these points to lower inflation. Quantum pricing, as a new pricing strategy, also represents a challenge for official statistics, which primarily raises issues of representativeness and the predictability of price changes. On the whole, the trends of the 21st century require economic agents to adjust properly and see new challenges as an opportunity rather than as an obstacle.

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6 Demographic trends of the future

One condition for presenting the macroeconomic path we deem to be sustainable is to outline the anticipated demographic trends of the future. If we only examine the current projections for global population, a decelerating rise in the present population of 7.7 billion can be expected, and thus the global population may peak at 10.9 billion in 2100. Within the framework of the present economic model, the rising global population – resulting from the unsustainable demographic policy of developing countries – further increases the size of the ecological footprint and global CO2 emissions, thereby exacerbating the sustainability problems.

However, if we examine the details of the process, two different trends take shape, neither of which is sustainable. The fertility rate in the developed countries is low, which leads to a decreasing population and rapid ageing. The process, in addition to increasing the number and ratio of dependants, has negative effect on innovation and imposes great burdens on the welfare provision systems. Meanwhile, the fertility rate in the lower income countries is very high, resulting in extremely fast growth of population, exceeding the growth rate of resources. Due to the different demographic trends, without successful intervention the weight of the individual regions will significantly change, which will redraw the currently known geopolitical maps. One example of this is that the share of European population will further decrease in world population: in 1950, the European population accounted for more than one fifth of the world population, while in 2015 it only accounted for 10 percent, and this ratio may fall to 6 percent by 2100.

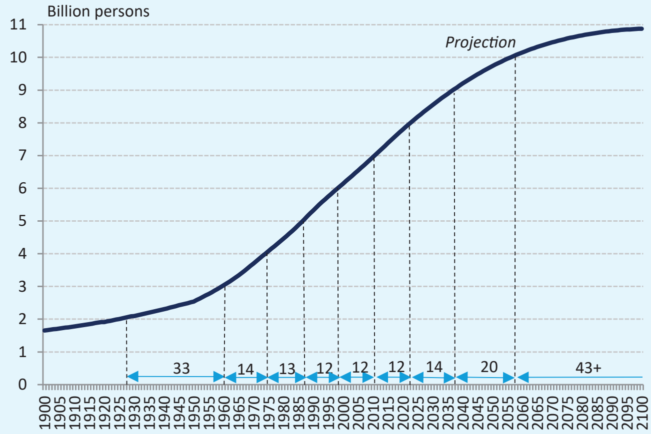
Public policies are also trying to resolve this problem. In the developed and middle-income countries, the governments support families and efforts to have children (for which Hungary also sets a good example), while developing countries are trying to contain unsustainable population growth. The ratio of the countries that wish to support an increase in the fertility rate with a variety of measures is the highest in Europe (66 percent). By contrast, 83 percent of the African countries introduce measures aimed to reduce fertility, one tool of which is to increase access to family planning opportunities. In addition, it is critically important that the economies that face strong population growth should develop sustainable growth ecosystems that ensure the reduction of environmental burdens.

6.1 Demographic trends across the world

6.1.1 THE WORLD'S POPULATION MAY FURTHER INCREASE

In the second half of the 20th century, global population rose dynamically. While it took 33 years for the number of inhabitants to rise from 2 billion to 3 billion, **in the past decades the global population has increased by another 1 billion persons every 12-14 years** (Chart 6-1).

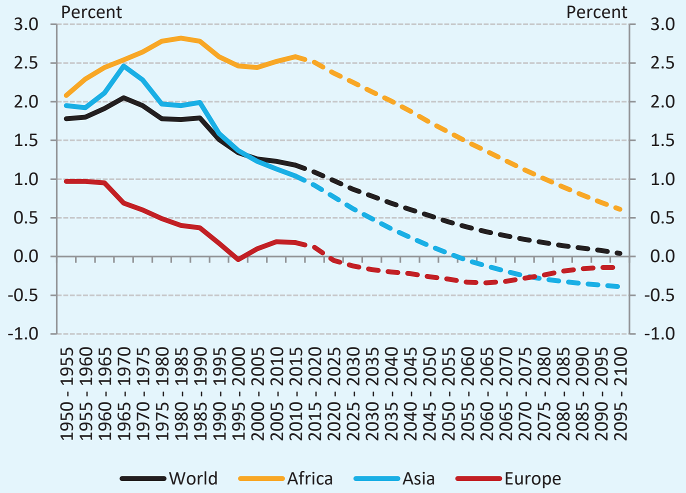
Chart 6-1: World population, 1900-2100



Note: The data before 1950 are extrapolated data; between 1900 and 1950 global population data are available with a frequency of 10 years. The chart shows actual figures between 1950 and 2015, now-casting between 2015 and 2020, and forecasting from 2020, based on the UN database.
Source: UN (2019a) population forecast, medium variant; History Database of the Global Environment

In 2019, the number of inhabitants on Earth is 7.7 billion, which may reach 8 billion in 2023 and 9 billion in 2037. Prior to reaching a population of 10 billion, estimated for 2057, the period of growth in the number of inhabitants by another 1 billion may last for 20 years. **Global population may peak in 2100 at 10.9 billion inhabitants**, i.e. in the second half of the century, global population is unlikely to rise by additional 1 billion persons in 43 years (UN, 2019a).

Chart 6-2: Average annual rate of the change in the number of inhabitants, 1950–2100 (percent)

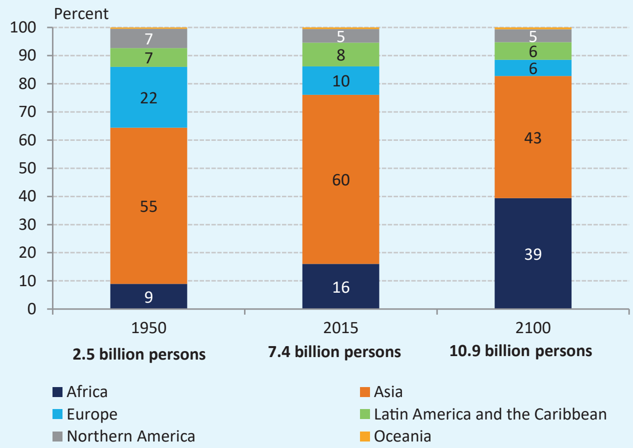


Note: The chart shows actual figures until 2015, and estimates thereafter. Positive values denote a rise in the number of inhabitants, while negative values denote a decrease.
Source: UN (2019a) population forecast, medium variant.

The growth rate of population may decline until the end of the century, since compared to the current values, the global fertility rate is expected to decline gradually until the end of the century. In the period of the most dynamic population growth, i.e. in the second half of the 1960s and the early 1970s, the number of inhabitants rose by 2 percent annually on average and since then the growth rate has been gradually decreasing (Chart 6-2). The growth of around 1 percent on average, observed currently in the countries of the world, may change to stagnation by the end of the century, i.e. the **rise in global population may come to an end**.

The trends underlying the rising global population vary substantially from continent to continent, which in the long run will result in a realignment of the weight of the individual regions. Among the world's continents, t**he number of inhabitants may rise to the largest extent in Africa due to the high fertility rate and rising life expectancy.** By 2050, the population of Africa may increase to 2.5 billion from 1.2 billion in 2015, and by the end of the century it may reach 4.3 billion. As a result of this, **the share of those living in Africa may rise to 26 percent by 2050 from 16 percent observed in 2015, and may come close to 40 percent by 2100** (Chart 6-3).

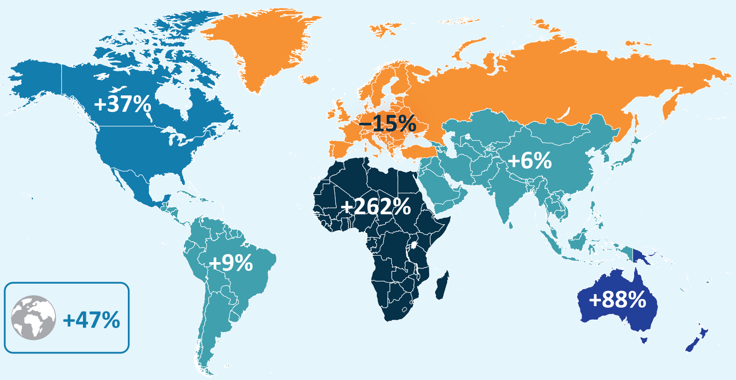
Chart 6-3: Global population and its distribution among the regions



Note: The continents follow the classification of the UN database.
Source: UN (2019a) population forecast, medium variant.

Asia may remain the continent with the highest number of inhabitants in the coming decades as well. The population of Asia may reach its maximum in the middle of the century: by 2055 it may rise to 5.3 billion from 4.4 billion registered in 2015, and then, with a gradual decline, it may fall to 4.7 billion by 2100. Considering that the population of Asia may be only moderately higher, merely by 6 percent, at the end of the century (Chart 6-4), the share of the inhabitants of the continent may **decrease** substantially **by 2100, to 43 percent from 60 percent registered in 2015.**

Chart 6-4: Change in the number of inhabitant in the continents of the world between 2015 and 2100 (percentage change)



Note: The continents follow the classification of the UN database.
Source: UN (2019a) population forecast, medium variant.

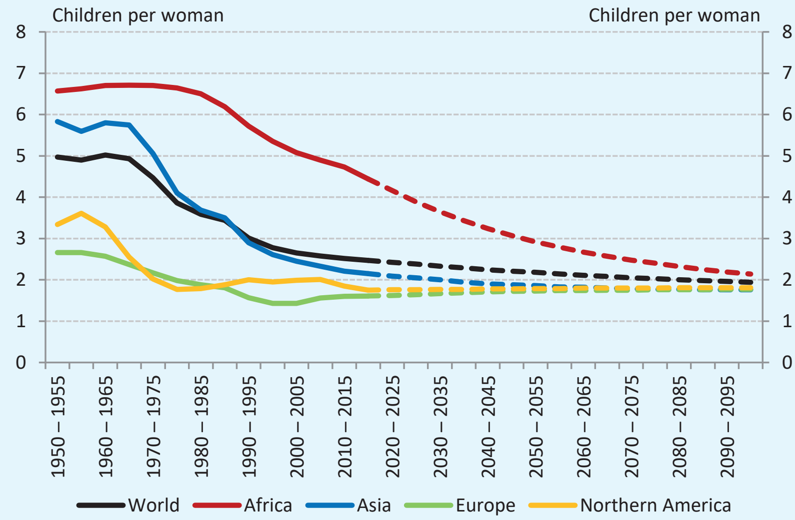
In the coming decades, Europe may be the only continent with a decreasing population. According to the UN's forecast, by 2050 the number of inhabitants in Europe may decrease to 710 million from 743 million registered in 2015, due to the fertility rate falling short of 2.1, i.e. the value necessary for reproduction, and in **2100 it may amount to 630 million in total.** As a result of this, the share of the European population will further decrease in world population: in 1950, European population accounted for 22 percent of the world population, while in 2015 only for 10 percent, and this ratio may fall to 6 percent by 2100.

6.1.2 FACTORS SHAPING THE NUMBER OF INHABITANTS

The different dynamics of the continents' population is explained by the differences between the two most important factors that determine the number of inhabitants, i.e. the fertility rate and life expectancy.

The decrease in the fertility rate is a global trend. In 1950-1955, the average number of children per woman in the countries of the world was around 5, but this ratio fell by one half, i.e. to 2.5 by 2015 (Chart 6-5). This means that with this fertility level one hundred women would give birth to 250 children during their life.

Chart 6-5: Fertility rate in the regions of the world, 1950–2100

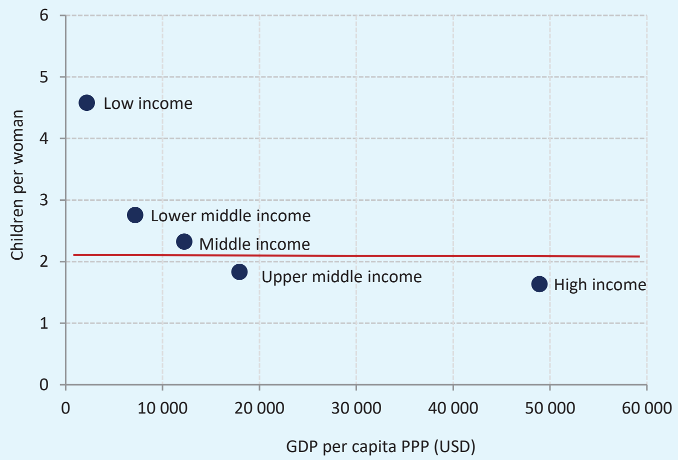


Note: The data are available for periods of five years. The chart shows actual figures until 2015, nowcasting between 2015 and 2020, and forecasting from 2020, based on the UN database.
Source: UN (2019a) population forecast, medium variant.

The fertility rate varies substantially by region. **In economically developed regions, the average number of children per woman is typically lower than in the developing countries**, and in most of the developed countries the fertility rate falls short of 2.1, i.e. the value necessary for reproduction of the population. When examining the relation between the groups of countries of different development levels and the fertility rate, we found that up to a GDP per capita level of roughly USD 12,000 the individual countries can remain above the fertility threshold (2.1 children) (Chart 6-6).

Experiences show that due to the demographic transition, the fertility rate decreases in parallel with an increase in economic development. In the course of the demographic transition, first a decline in the high mortality rate can be observed, followed by a decrease in the fertility rate within a few decades (Lee and Reher, 2011). Then, the number of working age population increases at a higher rate than that of the dependant population, since the number of children decreases year by year due to the decline in the fertility rate. **The regions of the world are in different stages of the demographic transition.** The decrease in the fertility rate is still in progress in the developing countries, while in the developed countries we can already observe low fertility and an ageing age pyramid.

Chart 6-6: Fertility rate and GDP per capita, 2017



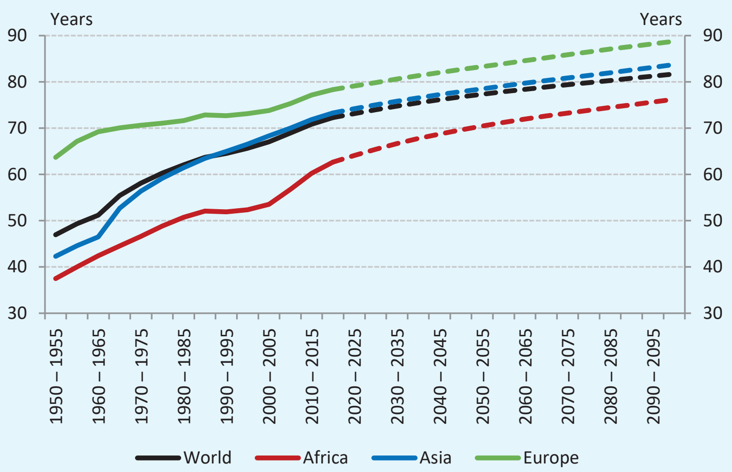
Note: The classification of income groups follows the World Bank's database.
Source: UN, World Bank.

Between 2010 and 2015, the average number of children per woman was 1.6 in Europe and 1.85 in North America, which is expected to remain below the reproduction threshold until the end of the century (Chart 6-5). The UN population forecast was prepared on the assumption that **in the countries with low fertility rates the number of children per woman may slightly increase in the coming decades.** This is due to the fact that the number of planned children is still around 2, and the increase in the fertility rate may also be supported by government measures over the long run (UN, 2019b). The ratio of the countries that wish to support an increase in the fertility rate with a variety of measures is the highest in Europe (66 percent) (UN, 2017a).

The strong growth in the population of Africa estimated for the coming decades is primarily caused by the fact that the fertility rate is extremely high and may remain at values over 2.1 until the end of the century. Based on the medium variant of the UN population forecast, in Africa the average number of children per woman may fall from the present 4.7 to below 3 in the first half of the 2050s, and then decline to 2.1 by 2100. Due to the gradual decline in the fertility rate, the growth rate of the continent's population is expected to decrease until the end of the century (Chart 6-2).

Differences in life expectancy have declined in recent decades, and by the end of the century, life expectancy may converge in the different regions (Chart 6-7). In 2015, the average life expectancy at birth in the countries of the world was 72.3 years, which may increase to 77 years by 2050 and to 82 years by 2100.

Chart 6-7: Life expectancy at birth in the regions of the world, 1950–2100



Note: The data are available for periods of five years. The chart shows actual figures until 2015.
Source: UN (2019a) population forecast, medium variant.

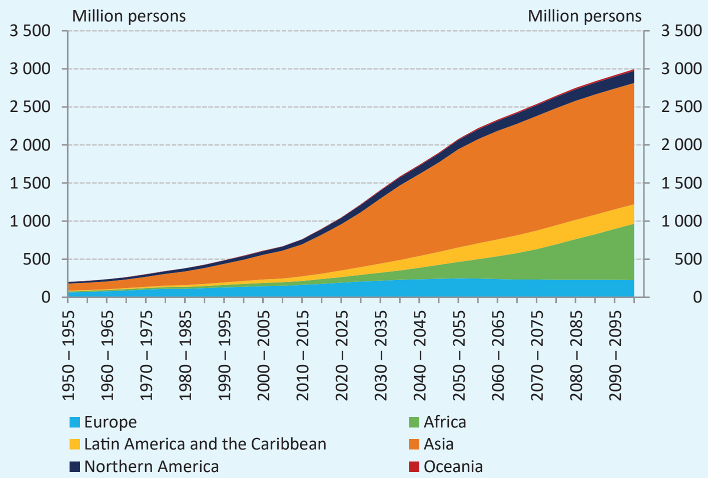
At present, the lowest life expectancy can be observed in Africa: in the first half of the 1980s the life expectancy at birth was only 50 years, while in the first half of the 2010s it already exceeded 60 years. At the same time, this value still lags substantially behind the figure for the developed regions, which was around 77-79 years in 2010-2015. A substantial part of the difference is attributable to infant mortality. **In the past 20 years, the mortality rate of children below the age of 5 decreased by almost half in Africa, which also made major contribution to the rise in the life expectancy at birth** (UN, 2017b).

In the coming decades, the difference in life expectancy between the developing and developed countries may further decrease, since looking ahead, by the first half of the 2050s life expectancy at birth in Africa may be around 70 years and at 76 years by the end of the century (UN, 2019a).

6.1.3 THE NUMBER OF THE ELDERLY MAY RISE IN ALL REGIONS

The population of the world may age to an unprecedented degree in the coming decades; the number of the elderly and their ratio within the population may significantly increase. The ageing of the population is caused by the decline in the fertility rate and the rise in life expectancy. These trends can be observed in all regions, albeit to different degrees.

Chart 6-8: Number of inhabitants above the age of 60 in the regions of the world, 1950–2100

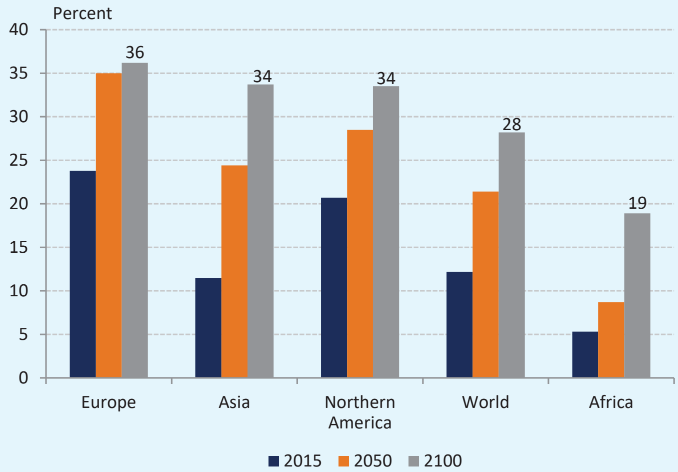


Note: The chart shows actual figures between 1950 and 2015, nowcasting between 2015 and 2020, and forecast from 2020.
Source: UN (2019a) population forecast, medium variant.

The number of people above the age of 60 may rise to an unprecedented degree: based on the medium variant of the UN population forecast, by 2050 the number may increase to 2 billion from 900 million registered in 2016, and to 3 billion by the end of the century (UN, 2019a). The number of inhabitants over the age of 60 may increase faster than the number of any of the younger age groups (UN, 2019b). At present, the elderly population is the highest in Asia, and their number may rise to 1.3 billion by 2050 from 511 million registered in 2015 (Chart 6-8).

By 2050, the ratio of the elderly within the population may rise to 21 percent from 12 percent registered in 2015, and it may amount to 28 percent in 2100 in the countries of the world (Chart 6-9). Ageing may vary by regions. Europe may be the continent with the oldest population in the coming decades as well; the ratio of the elderly within the population may rise to 35 percent by 2050, which in the second half of the century may only increase moderately. In Asia, where at present the ratio of inhabitants above 60 within the population amounts to only 12 percent, the ratio of the elderly may rise to 24 percent and 34 percent by 2050 and 2100, respectively.

Chart 6-9: Ratio of inhabitants above the age of 60 in the continents of the world in 2015, 2050 and 2100 (as a percentage of total population)



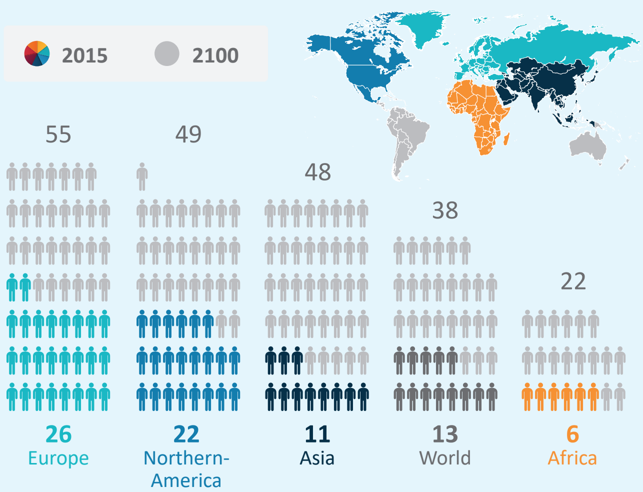
Source: UN (2019a) population forecast, medium variant.

Ageing affects even those countries where the age structure of the population is dominated by young generations. In 2015, in Africa the ratio of inhabitants above the age of 60 within the population was merely 5 percent, while this ratio may rise to 9 percent by 2050 and to 19 percent by 2100. This means that by the end of the century roughly every fifth African inhabitant may be older than 60. In parallel with this, by 2050 the number of the elderly may rise more than threefold compared to the value in 2015 in Africa, while by the end of the century it may exceed 800 million.

Population ageing results a rise in the ratio of the elderly to the younger generation, thereby increasing the burdens of the economically active population. One measure of population ageing is the old-age dependency ratio, which shows the ratio of population aged 65 and above compared to the working-age population (15-64 years).

In coming decades, the old-age dependency ratio may show an unprecedented rise in the countries of the world due to ageing. By 2050, the ratio may rise to 25.3 percent from 12.6 percent in 2015, while the current value may increase threefold by 2100 (Chart 6-10). This means that while in 2015 there were 13 elderly people per 100 working-age persons, in 2050 their number will be almost twice as high, i.e. 25. **The index simultaneously captures the effect of two demographic trends increasing the dependency ratio:** on the one hand, due to the decline of the fertility rate smaller and smaller new generations may be born in the future, and on the other hand, due to the rise in life expectancy, the elderly may live longer compared to previous decades.

Chart 6-10: Old-age dependency ratio in the regions of the world, in 2015 and in 2100 (percent)



Source: UN (2019a) population forecast, medium variant.

The average value for the countries of the world masks major regional differences. The old-age dependency ratio may remain the highest in Europe: in Europe, there were 26 elderly people per 100 inhabitants of working age in 2015, while in 2050 there will be almost twice as many, i.e. 49, elderly people per 100 inhabitants of working age (i.e. **2 inhabitants of working age will provide for 1 elderly inhabitant**). In the second half of the century, the ratio may increase further, and in 2100 it may be as high as 55 percent.

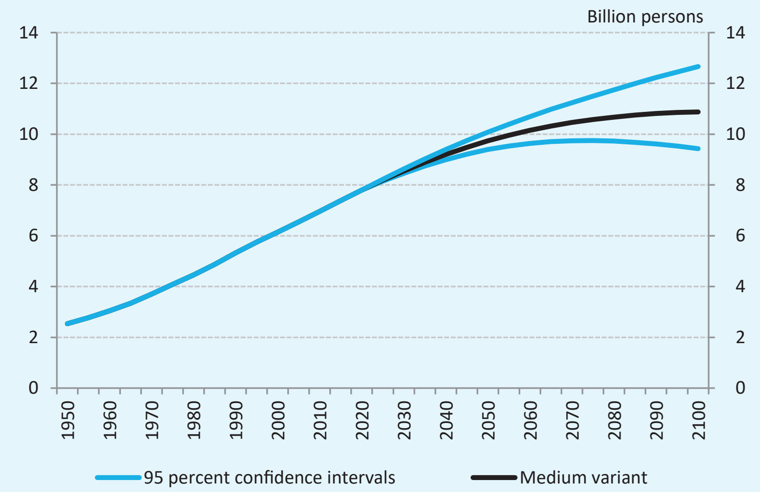
Finally, it should be noted that although the old-age dependency ratio suggests a major increase in the burdens of the working age inhabitants, the ratio is a pure demographic indicator, i.e. **the actual economic effects of ageing may change differently.** The old-age dependency ratio ignores labour market activity, i.e. the number of the working age population actually appearing in the labour market, and it also fails to reckon with the possibility that individuals may opt for longer active careers in the event of longer life expectancy and better health conditions.

6.1.4 UNCERTAINTIES SURROUNDING THE NUMBER OF INHABITANTS

The results of the population projection presented above are surrounded by major uncertainties in the very long run, and thus the results must be treated prudently. The number of inhabitants may follow different scenarios, if the assumptions underlying the population forecast do not materialise. Of the factors determining the number of inhabitants, **primarily the fertility rate is surrounded by major uncertainties,** while the future number of inhabitants is mostly determined by the birth rate.

The global population, also considering the uncertainties, most probably may follow an upward trend until the 2050s. In 2030, with a probability of 95 percent, the number of the world's inhabitants may be between 8.5 and 8.6 billon, and in 2050 between 9.4 and 10.1 billion (Chart 6-11). The longer the projection period we examine, the larger the band of uncertainties surrounding the number of inhabitants. In 2100, the number of inhabitants may be in the range of 9.4 and 12.7 billion.

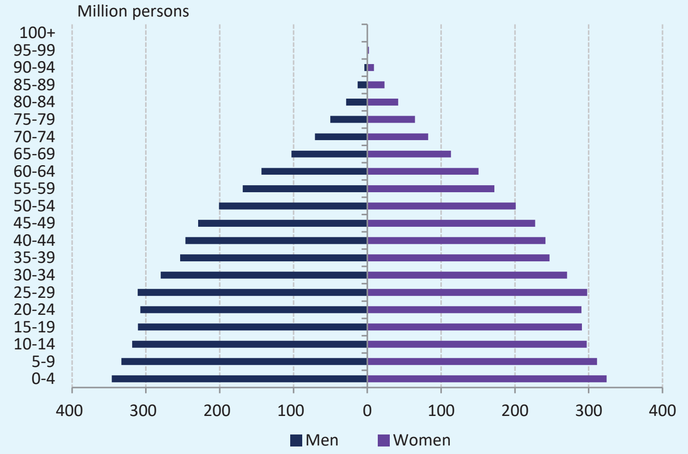
Chart 6-11: Global population based on the medium variant and the 95 percent confidence interval thereof



Note: The chart shows actual figures between 1950 and 2015, nowcasting between 2015 and 2020, and forecasting from 2020.
Source: UN (2019a) population forecast.

At a horizon of a few decades, the future size of the population is influenced – in addition to the fertility rate and the life expectancy – **by the current structure of the population**. **At present, the global age pyramid shows an increasing population**, with larger young generations and smaller elderly generations (Chart 6-12). By 2050, two thirds of the anticipated growth in population will be determined by the present structure of the population, since there are large groups of childbearing age all over the world (UN, 2019b).

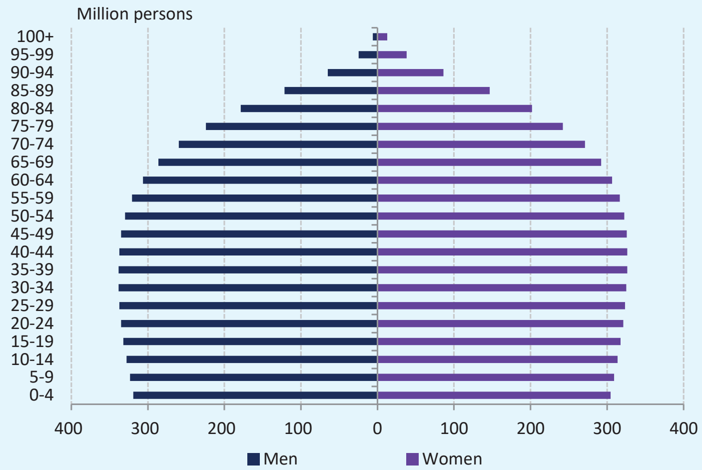
Chart 6-12: World population age pyramid, 2015



Source: UN.

A large part of the population growth estimated until 2050 is caused by the fertility rate of over 2 observed in the developing countries, and the gradual rise in life expectancy (UN, 2019b). If the demographic trends develop in line with assumptions included in the population forecast, at **the end of the century the age pyramid of the global population may already show stagnation in the number of inhabitants** (Chart 6-13), with large number of elderly inhabitants.

Chart 6-13: World population age pyramid, 2100



Source: UN (2019a) population forecast, medium variant.

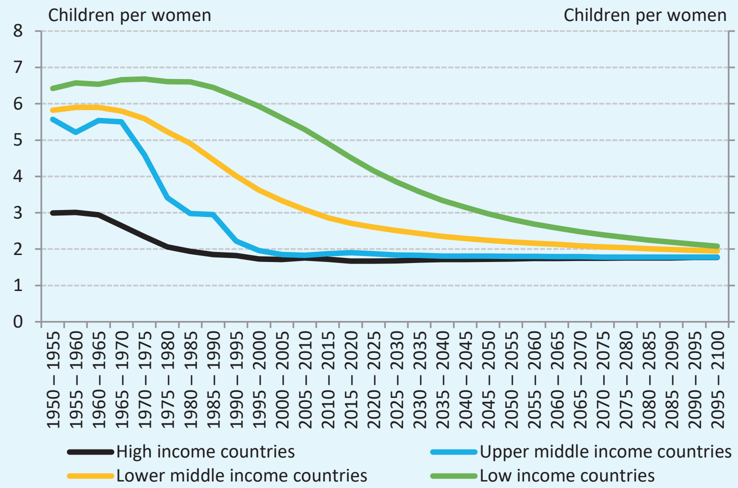
At the same time, in respect of Europe it should be noted that the baseline scenario of the UN population forecast anticipates a gradual increase in the fertility rate, which – based on the assumption – may rise to 1.77 by 2100 from the average value of 1.6 estimated for the second half of the 2010s. If the assumed rise in the number of children per woman does not materialise during the century, **the population of Europe may be even less than the figure of 630 million estimated for the end of the century, in 2100.**

6.2 Is the current growth in global population sustainable in the long run?

6.2.1 TWO MODELS OF THE DEMOGRAPHIC TRENDS

Based on the global demographic trends, two types of demographic models seem to take shape in the countries of the world, depending on the stage of the demographic transition which the respective country is in. On the one hand, **there is the group of countries with low fertility rates and a more developed economy**, and on the other hand, **the group of low income countries with high fertility rates.**

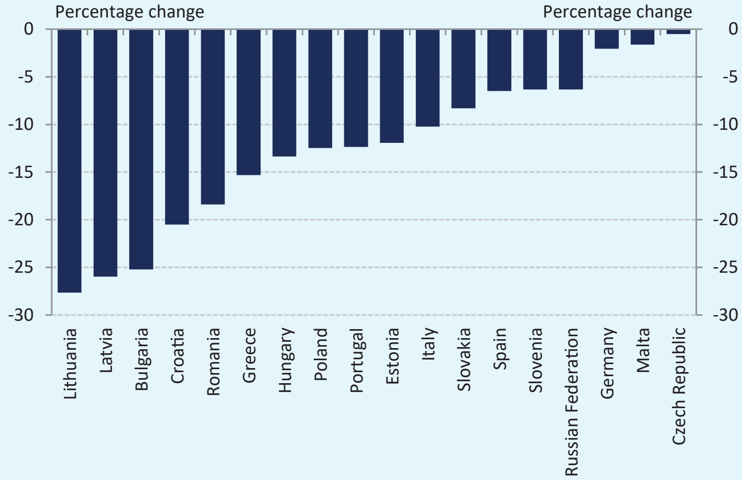
Chart 6-14: Fertility rates in countries from different income groups, 1950–2100



Note: The data are available for periods of five years. The chart shows actual figures until 2015. The diagram shows nowcasting between 2015 and 2020, and forecasting from 2020. The allocation of countries to income groups follows the classification of the World Bank.
Source: UN (2019a) population forecast, medium variant

In the high-income and upper-middle-income countries the fertility rate is low, since it falls short of the value of about 2.1, necessary for reproduction, and due to this, the number of inhabitants is expected to decrease in the coming decades. Between 2019 and 2050, the population may decrease in 55 countries due to the low fertility rate (UN, 2019b), which includes a number of East European and South European countries (Chart 6-15). **In some of the countries**, e.g. in Lithuania, Latvia and Bulgaria, **the population may decrease by more than 20 per cent** by the middle of the century. In addition, the population is also expected to decline in Greece, Portugal, Italy, Russia and Germany. In some of the economically developed countries (e.g. in the Scandinavian countries, the United Kingdom, the Unites States and Canada), the fertility rate also falls short of the threshold value necessary for reproduction, and it is unlikely to reach it in this century; nevertheless, the UN population forecast projects an increase in the number of inhabitants. This is primarily attributable to the assumption that the earlier international migration trends will continue, i.e. in these countries immigration may result in an increasing population, which, however, may lead to increasing social tensions.

Chart 6-15: Change in the number of inhabitants in countries with decreasing population between 2015 and 2050



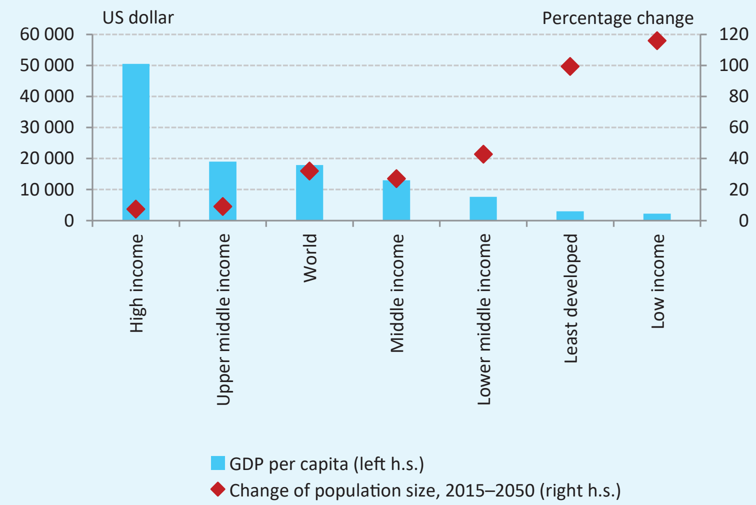
Note: The chart shows the change in the number of inhabitants in countries with decreasing population between 2015 and 2050.
Source: UN (2019a) population forecast, medium variant.

The low fertility rate and declining population is not sustainable in the long run. Across the world, 62 percent of the countries with fertility rates below the reproduction level introduced recently government measures aimed at raising the number of children. **29 of the 44 European countries encourage families to have children with various measures (e.g. family benefits, tax allowances, flexible working hours) in order to increase the number of births (UN, 2017a).**

The decline in the number of inhabitants may have major economic consequences in the long run. The decrease in the number of the working age population may have an unfavourable effect on economic growth, since the ageing society has a negative impact on innovations due to the slower adaptation capability (Bloom et al., 2010), while the ageing of the labour force **may curb the productivity growth rate** over the long run (Aiyar et al., 2016; IMF, 2017). **The ageing of the population generates challenges for the social insurance provisioning systems as well.** The decrease in the working age population – *ceteris paribus* – may reduce contribution revenues, while due to the increasing number of the elderly population the number of beneficiaries may increase both in the pension system and the healthcare system.

The high fertility rate and rapid population growth which characterises the developing world also cannot be regarded as a demographic model that is sustainable over the long run. One of the biggest challenges of the 21st century is represented by the fact that **the countries with the fastest population growth are also the countries with the lowest incomes** (Chart 6-16). In the 47 states, allocated to the group of least developed countries, the annual growth rate of the population is currently 2.3 percent on average, and the population of this group may double by 2050 from 940 million persons registered in 2015 (UN, 2019a). The group of economically least developed countries includes several Sub-Saharan African countries and a few small island countries. The latter may also be areas strongly affected by climate change in the future, due to rising sea levels (e.g. Bissau-Guinea, Vanuatu; UN, 2019b).

Chart 6-16: Change in GDP per capita and number of inhabitants between 2015 and 2050 in certain country groups of the world



Note: The GDP per capita defined on the basis of purchasing power parity is from 2018.
Source: Medium variant of the UN (2019a) population forecast, World Bank.

As regards the continents, in the coming decades the fastest growth in the population can be expected in Africa. **83 percent of the African countries introduced measures aimed at reducing fertility**, one means of which is to increase access to family planning opportunities (UN, 2017a). In terms of sustainable development, in these countries it represents a challenge whether in parallel with the fast growth of the population they will be able to **provide proper access to education and healthcare**, and whether a **sufficient number of jobs will be available on the labour market** for the large generations entering working age. In addition, the unsustainable population growth in the developing world may increase environmental burdens and result in the exhaustion of natural assets.

6.2.2 SUSTAINABLE DEVELOPMENT TARGETS SET BY THE UN

The **Sustainable Development Framework** (Agenda 2030) adopted by the UN in 2015, wishes to achieve an equilibrium between the three key dimensions of sustainable development, i.e. the economy, society and the environment. Based on the UN's objectives, **in order to achieve sustainable development, in addition to steady economic growth, efforts should be made for balanced social development and the protection of the environment** (Chart 6-17).

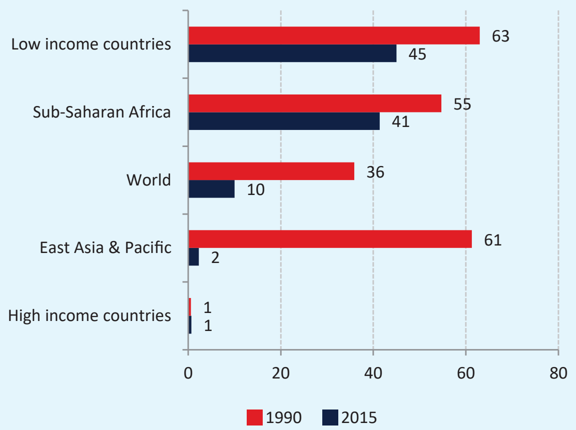
Chart 6-17: Sustainable development targets set by the UN

Source: www.ensz.kormany.hu

With the fast population growth in the developing countries, it is increasingly difficult to achieve the objectives serving environmental and social sustainability: the rise in the global population results in increasing environmental burdens, the education and health systems need to keep pace with increasing demand, and it is more difficult to reduce poverty and famine (Lutz, 2016). Moreover, a large part of the future population growth may be concentrated in the less developed regions.

Although in the past period major progress has been made in the eradication of poverty, the objective is unlikely to be met by 2030, since the ratio of those living in extreme poverty remains high in the low-income countries. In 1990, the ratio of those living in extreme poverty was still 36 percent in the countries of the world, which fell to 16 percent by 2010 and to 10 percent by 2015 (UN, 2019c). This means that 10 percent of the world's population, i.e. about 700 million people must live on less than USD 1.9 per day, a major part of whom live in Sub-Saharan Africa. The fact that in Asia the number of those living in extreme poverty decreased substantially has made a strong contribution to reducing the ratio. According to the UN's forecast, **6 percent of the world's population may live in extreme poverty in 2030**, while the ratio may remain high in Sub-Saharan Africa (UN, 2019c).

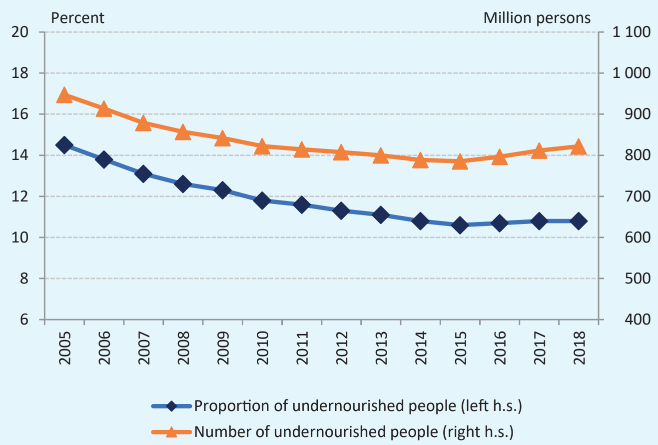
Chart 6-18: Ratio of those living in extreme poverty within the population (percent)



Note: The chart shows the ratio of those inhabitants within the population, who live on less than USD 1.9 per day.
Source: World Bank.

In parallel with the population growth, famine is a significant global problem, and the favourable trend of eliminating it has faltered. In 2017, 10.9 percent of the world's population – i.e. every ninth person, 821 million people in total – suffered from shortage of food all over the world (UN, 2019c).

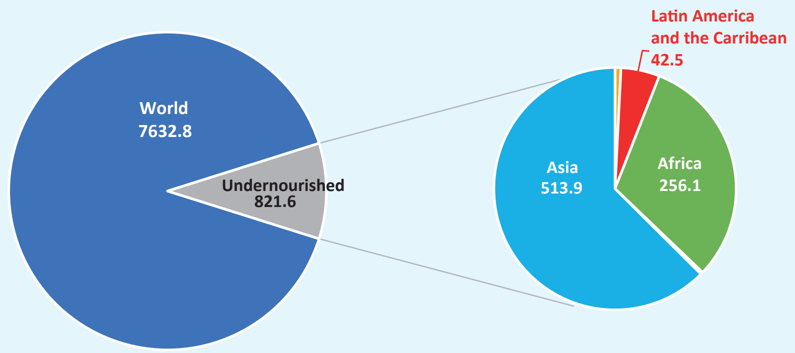
Chart 6-19: Number of the undernourished and their ratio within the world's population, 2005–2018



Note: The data for 2018 is nowcasting.
Source: FAO.

In 2015, the strong downward trend in undernourishment observed in the past decades faltered, and the ratio and number of the undernourished within the population did not decline further in the past three years (FAO, 2019). **One third of the inhabitants suffering from food shortage live in Africa, with the rise in extreme weather conditions playing a major role in this.** Of the countries of Sub-Saharan Africa, in the countries susceptible to drought the ratio of the undernourished rose from 17 percent close to 22 percent in recent years, while in other countries of the region, the ratio of the malnourished declined (FAO, 2019).

Chart 6-20: Distribution of the undernourished among the regions of the world, 2018 (million persons)



Source: FAO.

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List of charts and tables

Count István Széchenyi

(21 September 1791 – 8 April 1860)

Politician, writer, economist, minister for transport in the Batthyány government whom Lajos Kossuth referred to as ‘the greatest Hungarian’. His father, Count Ferenc Széchényi established the Hungarian National Museum and Library; his mother, Julianna Festetich was the daughter of Count György Festetich, the founder of Georgikon, an institution for the teaching of agricultural sciences.

With his ideas – whose message remains relevant even today – and his activities both as a writer and a politician, István Széchenyi laid the foundation for modern Hungary. He is one of the most eminent and significant figures in Hungarian politics whose name is associated with reforms in the Hungarian economy, transportation and sports. He is also known as the founder and eponym of numerous public benefit institutions, a traveller all across Europe and an explorer of England as well as the champion of economic and political development at the time. István Széchenyi recognised that Hungary needed reforms in order to rise, and considered paving the way for a Hungary set on the path of industrialisation and embourgeoisement to be his calling in life.

Published in 1830, his Credit outlined the embourgeoisement of Hungary and summarised its economic and social programme. Count Széchenyi intended this writing to make the nobility aware of the importance of the country’s desperate need for a social and economic transformation. Another work of his, Stádium [Stage of Development] (1833) listed the cornerstones of his reform programme in 12 points, including the voluntary and compulsory liberation of serfs; the abrogation of avicitas (inalienable status of noble property); the right of possession for the peasantry; and the freedom of industry and commerce. This work of Széchenyi already conveyed the idea of equality before the law and the general and proportionate sharing of taxation.

After the revolution in 1848 István Széchenyi joined the Batthyány government and as minister embarked vigorously on implementing his transportation programme.

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