INDUSTRY AND INNOVATION

OECD Green Growth Papers
2018-05

China's Progress Towards Green Growth

AN INTERNATIONAL PERSPECTIVE

October 2018

OECD GREEN GROWTH PAPERS

The OECD Green Growth Strategy, launched in May 2011, provides concrete recommendations and measurement tools to support countries' efforts to achieve economic growth and development, while at the same time ensuring that natural assets continue to provide the ecosystem services on which our well-being relies. The strategy proposes a flexible policy framework that can be tailored to different country circumstances and stages of development.

This paper has been authorised for publication by Mr. Anthony Cox, Deputy Director, Environment Directorate. OECD Green Growth Papers should not be reported as representing the official views of the OECD or of its member countries. The opinions expressed and arguments employed are those of the author(s).

This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

OECD Green Growth Papers aim to describe preliminary results or research in progress by the author(s) and are published to stimulate discussion on specific topics and obtain feedback from interested audiences. They complement the OECD Green Growth Studies series, which aims to provide in-depth reviews of the green growth issues faced by different sectors.

Comments on Green Growth Papers are welcomed, and may be sent to:

OECD Green Growth Unit, 2, rue André Pascal, 75775 PARIS CEDEX 16, France
or by email to greengrowth@oecd.org

OECD Green Growth Papers are published on:

www.oecd.org/greengrowth

Please cite this paper as:

Linster M. and Yang, C. (2018), "China's Progress Towards Green Growth: an international perspective", *OECD Green Growth Papers, No. 2018/05*, OECD Publishing, Paris.

© OECD (2018)

You can copy, download or print OECD content for your own use, and you can include excerpts from OECD publications, databases and multimedia products in your own documents, presentations, blogs, websites and teaching materials, provided that suitable acknowledgment of OECD as source and copyright owner is given.

All requests for commercial use and translation rights should be submitted to rights@oecd.org.

China's progress towards green growth
An international perspective

Table of contents

Abstract **3**

Acknowledgments **4**

1. China's economy and its industry in a global perspective **5**

1.1. Emergence as the world's largest manufacturer 5
1.2. Moving up the value chain 8
1.3. Innovation as an engine for growth 11
1.4. Industrial expansion and productivity growth 11
1.5. Environmental implications 12

2. China's economy and industry in a green growth perspective **14**

2.1. Overview of China's position with respect to green growth 14
2.2. The natural asset base of the Chinese economy 16
2.3. The environmental and resource productivity of the Chinese economy 18
2.3.1. Multi-factor productivity and other sources of growth 19
2.3.2. Carbon productivity 19
2.3.3. Energy productivity and renewables 20
2.3.4. Material productivity and waste 21
2.3.5. Air pollution and human health 23
2.4. The environmental and resource productivity of the Chinese industry 25
2.5. Economic opportunities from green growth and the role of environmental policies and innovation 28
2.5.1. Policy context and stringency 28
2.5.2. Economic instruments and environmental taxation 30
2.5.3. Innovation and technology development 31

3. China's prospects for aligning environmental and growth objectives in the context of industrial upgrading **33**

3.1. Synergies between industrial and environmental policies 33
3.2. Effective industrial upgrading and restructuring 34
3.3. Effective environmental policies for industry 35
3.4. Effective environmental governance and policy coordination 35
3.5. Effective environmental information systems 36

References **37**

Tables

Table 1. Environmental targets in China's 11th, 12th and 13th Five Year Plans (FYP) 29

Figures

Figure 1. The Chinese economy has undergone profound structural changes 6
Figure 2. The weight of state-owned enterprises (SOE) in the Chinese economy has shrank 8
Figure 3. China's domestic value added of manufacturing exports has caught up fast with the OECD level and comes increasingly from high-tech sectors 9
Figure 4. China is moving upward in the value-chain 10
Figure 5. Productivity growth has been declining since the crisis 12
Figure 6. Environmental profile of the Chinese industry* 13
Figure 7. Overview of China's progress towards green growth 15
Figure 8. China has been drawing heavily on produced and natural capital to generate growth at the expense of the environment 18
Figure 9. Carbon productivity is improving but remains low 20
Figure 10. China's energy mix is slowly diversifying, but consumption remains high and coal dominates 21
Figure 11. Non-energy material productivity and materials mix 22
Figure 12. China decoupled some environmental pressures faster than OECD countries 24
Figure 13. Decoupling of SOx and NOx emissions first occurred at a lower level of economic development than in OECD countries 24
Figure 14. Air pollution by fine particulates is high and population exposure raises concerns 25
Figure 15. Environmental profile of the Chinese industry* 26
Figure 16. Energy intensities have decreased in many manufacturing sectors, 2004-2014 27
Figure 17. Waste generated by industry is growing, but is increasingly recovered 28
Figure 18. Environmental policies have become more stringent 30
Figure 19. Environmentally related taxation is increasingly used 31
Figure 20. Environmentally-related technologies are developing rapidly 32

Boxes

Box 1. China's environmental information system and indicators 16
Box 2. Aligning medium-term economic growth and environmental objectives in China – A research study 34

Abstract

This report illustrates China's progress towards green growth from an international perspective, with focus on industry and the interplay between industrial development and environment. It starts with depicting the structural shifts that the Chinese economy, in particular its industry, has undergone since the early 1990s. It briefly discusses the driving forces behind China's emergence as global manufacturing powerhouse, and the environmental implications of this rapid phase of industrialisation. It also assesses China's position vis-à-vis green growth using the OECD green growth measurement framework and indicators.

The findings suggest that China has made great strides towards improving the environmental and resource productivity of its economy, but more opportunities can be exploited for greater efficiency gains that are vital to the shift to a low carbon, resource efficient and competitive economy. They also indicate that the policies in place, though showing first results, remain insufficient to cope with increasing environmental pressures and with historical and cumulated pollution loads. Further progress will largely depend on the country's capacity to integrate environmental aspects into decision-making in all policies and sectors, and at all levels, and ensure that industrial and environmental policy objectives and measures are well aligned and mutually supportive.

Acknowledgments

This working paper presents selected results from a project conducted by the OECD jointly with the Development Research Centre of the State Council of China (DRC) in 2016-17. The project dwelled upon the best ways to promote industrial restructuring and a "New Productive Revolution" in China, while improving the environmental and resource efficiency of the economy.

The paper was co-authored by Myriam Linster (OECD Environment Directorate) and Chan Yang (OECD Global Relations Secretariat). The opinions expressed and arguments employed herein are those of the authors. The contributions by Dr. Weiming Li (Institute for Resource and Environmental Policies, Development Research Centre of the State Council of China), Antonio Fanelli (OECD Global Relations Secretariat), Brendan Gillespie (Green Solutions Network), Tomasz Koszluk (OECD Economics Department) and Krzysztof Michalak (OECD Environment Directorate) are gratefully acknowledged. Kumi Kitamori (Head of Division on Green Growth and Global Relations in the Environment Directorate), and Irène Hors (Head of Division on Strategic Partnerships and New Initiatives in the Global Relations Secretariat) provided project oversight.

An overview of key messages included in this working paper was presented to the OECD Working Party on Environmental Information at its annual meeting in November 2016.

The project benefitted from the financial support of the United Kingdom, the Netherlands and the Energy Foundation China. The opinions expressed and arguments employed herein do not necessarily reflect the views of the United Kingdom, the Netherlands or the Energy Foundation China.

The figures presented in this report are based on information and data available up to July 2017. Data were obtained from OECD, other international sources and various national sources from China.

1. China's economy and its industry in a global perspective

The Chinese economy has expanded by a factor of 30 in real terms since the reforms initiated in 1978, achieving middle-income status and lifting hundreds of millions of its citizens out of poverty (Figure 1.A). This growth performance was underpinned by fundamental structural changes in the economy. The share of agriculture in GDP fell from roughly 30% in 1978 to less than 10% in recent years (Figure 1.C). The share of industry[1] has remained more or less stable at above two-fifths of GDP, a higher level than in other emerging economies (Figure 1.B). The sector has been a driving force in China's economic transformation and urbanisation, growing at a faster rate than GDP for a significant part of the three recent decades, albeit at a slower pace since the global financial crisis (Figure 1.D).

The service sector has achieved the most impressive growth, doubling its share of the economy from 25% at the outset of reforms to over 51% in 2017. It overtook manufacturing as the main contributor to GDP growth in 2012. Nevertheless, compared to OECD and even to some BRIIS[2] economies, the sector remains relatively small in China (Figure 1.E). As services tend to be labour intensive and less polluting than manufacturing, the sector will play an increasingly important role in sustaining China's economic growth and its transition to a low-carbon, resource-efficient development model. The recent slowdown in manufacturing growth also reflects China's continuous structural adjustment and rebalancing towards services, against the backdrop of a shrinking labour force and slower growth in investment and export.

1.1. Emergence as the world's largest manufacturer

Today, China is the world's largest producer of industrial goods, having successively displaced Germany, Japan and the United States during the first decade of the 21st century (Figure 1.F). It accounted for over a quarter of total world manufacturing value added in 2016 and is likely to continue rising in the coming years. In the broader industrial sector, China's total industry value-added at market exchange rates amounted to USD 4.5 trillion in 2016, well ahead of the European Union (USD 3.7 trillion), the United States (USD 3.5 trillion) and the BRIIS economies (USD 1.7 trillion) (World Bank World Development Indicators, OECD National Accounts database). It makes and sells a vastly diverse range of goods, from low-end labour-intensive sectors like textiles and garments to high-end knowledge-intensive segments like electronic products and transport equipment. In 2015, it was the source of approximately half of the global supply of crude steel[3] (808 million tonnes), coal[4] (3.5 billion tonnes) and cement[5] (2.4 billion tonnes), and more than a quarter of world's supply of motor vehicles[6] (24.5 million units). It is also the world's largest

1 Industry refers to the mining and quarrying, manufacturing, energy (electricity and heat production and supply) and construction sectors.

2 BRIIS is an acronym for Brazil, Russia, India, Indonesia and South Africa.

3 World Steel Association

4 International Energy Agency

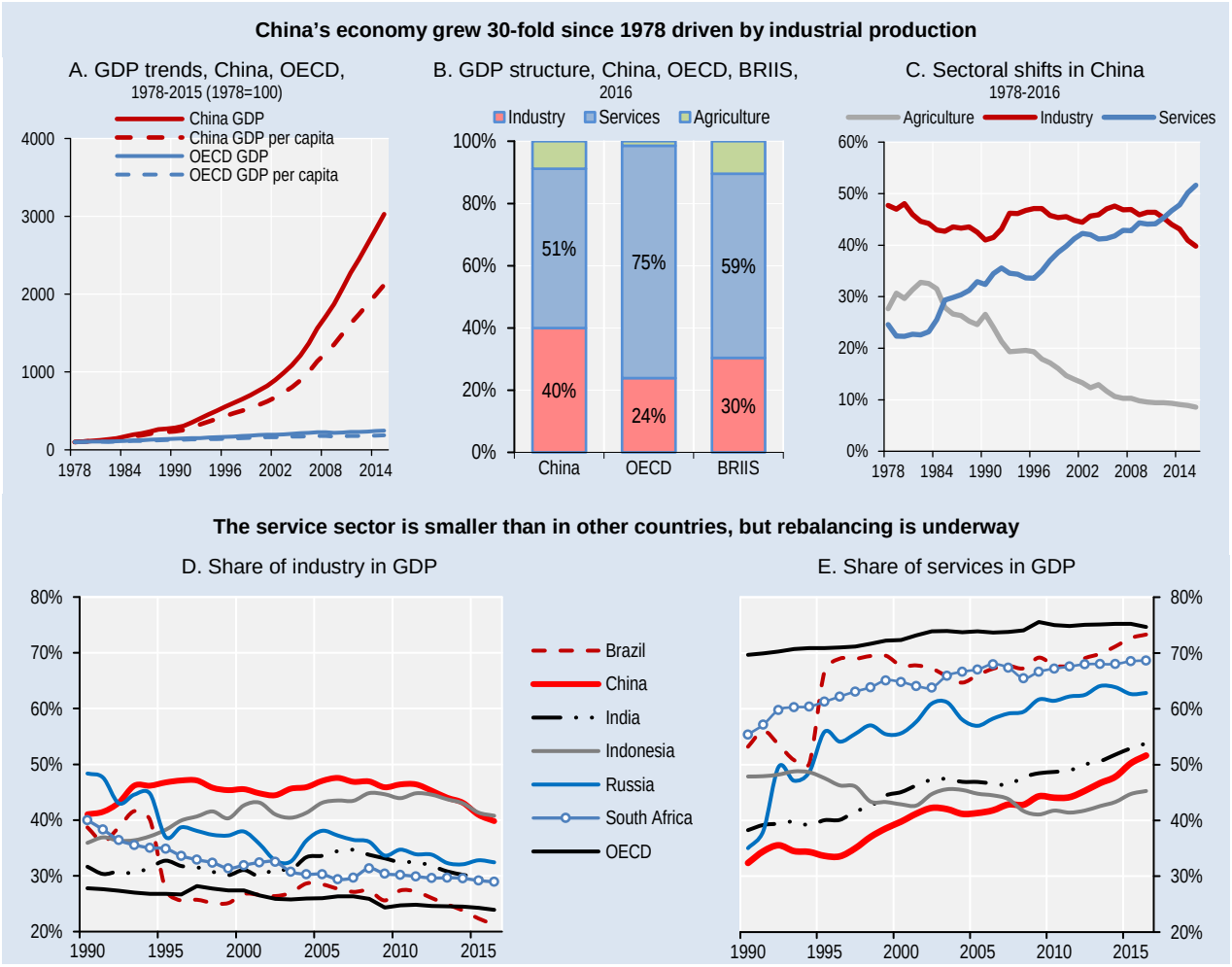
5 European Cement Association

6 International Organisation of Motor Vehicle Manufacturers

producer of ships, high-speed trains, robots, chemical fibre, machine tools, cell phones, computers, and a number of metals and home appliances.

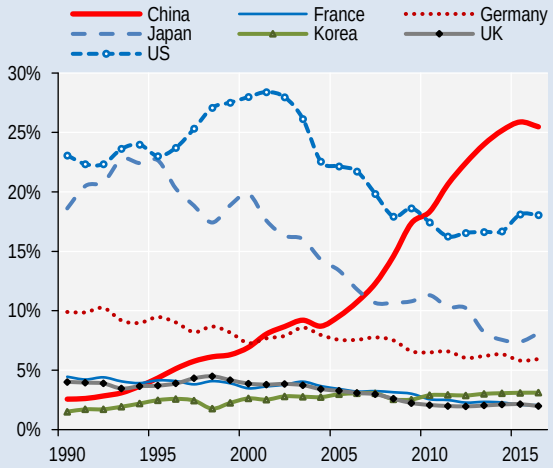
Rapid industrialisation has been accompanied by a steady increase in employment in the manufacturing sector in China, particularly in the immediate aftermath of its entry in WTO (Figure 1.G). By some estimates, China captured more than 40% of global manufacturing employment in 2010, up from 29% in 1990. In contrast, most OECD countries have experienced a persistent decline in manufacturing jobs: the share of manufacturing in total employment in the OECD area has dwindled from about a quarter to a third in the early 1970s, to 10% or lower today. These global shifts in manufacturing employment reflect major changes in production strategies among firms today, particularly those of multinational enterprises, as global value chains have become more extended and widespread (OECD, 2015a).

Figure 1. The Chinese economy has undergone profound structural changes

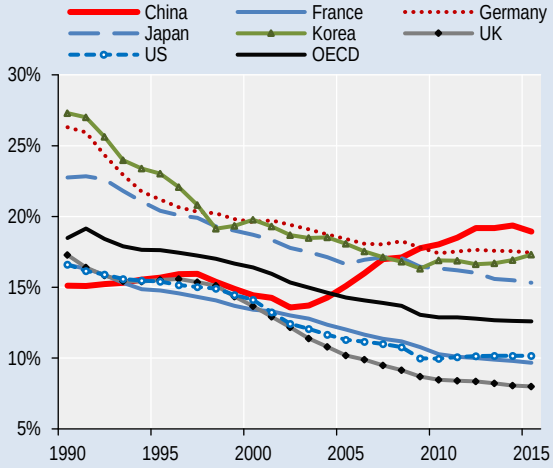


China became the world's leading manufacturer in 2010

F. Share of world manufacturing value added, 1990-2016



G. Manufacturing jobs as a share of total employment, 1990-2015



Note: Industry refers to mining & quarrying, manufacturing, energy (electricity & heat production & supply) and construction.

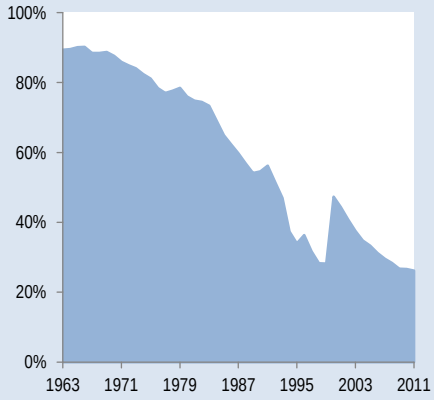
Source: OECD National Accounts database, World Bank World Development Indicators database, United Nations National Accounts Main Aggregates Database.

China's emergence as a global manufacturing powerhouse has been driven primarily by the combination of a strong foreign demand and a large and fast-expanding domestic market. The interactions between industrialisation, urbanisation, real estate and infrastructure development have been mutually reinforcing and created strong demand for industrial products. China's accession to the WTO in 2001 and its integration in the global value chains (GVCs) were also key factors establishing its position as the engine of global GDP and trade growth. Over the past decades, manufacturing industries have diversified into a widening range of products. Chinese industry has been competitive internationally for a sustained period of time: it has maintained a net current account surplus since 1995, reaching its peak in 2007 at nearly 10% of GDP (World Development Indicators).

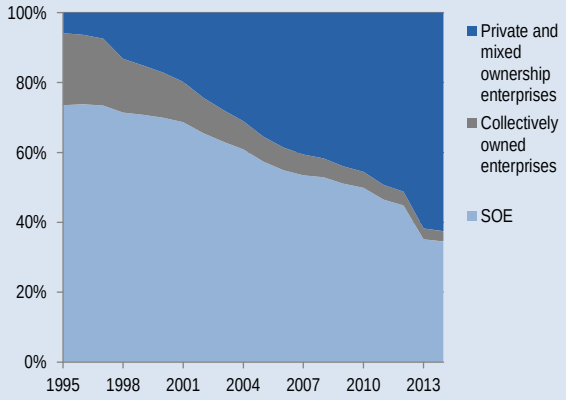
At the same time, the transition from a centrally planned to a more open market economy has led to more efficient resource allocation: reforms in the state-owned and collective sectors during the late 1990s and early 2000s, along with measures to facilitate private sector development and encourage foreign capital investment, have unleashed efficiency gains and productivity growth in the manufacturing sector. Significant transformations were recorded in the corporate structure: the weight of state-owned enterprises (SOEs) in total industrial output decreased from above 70% during the 1960s and 1970s to below a third since 2005 (Figure 2.A). Its contribution to job creation has also declined dramatically, and has gone from generating more than 70% of total employment in the 1990s to just above a third in 2014 (Figure 2.B).

Figure 2. The weight of state-owned enterprises (SOE) in the Chinese economy has shrank

A. Share of SOEs in total industrial output



B. Share of employment by ownership type



Sources: China Industrial Statistics Yearbook, varied issues.

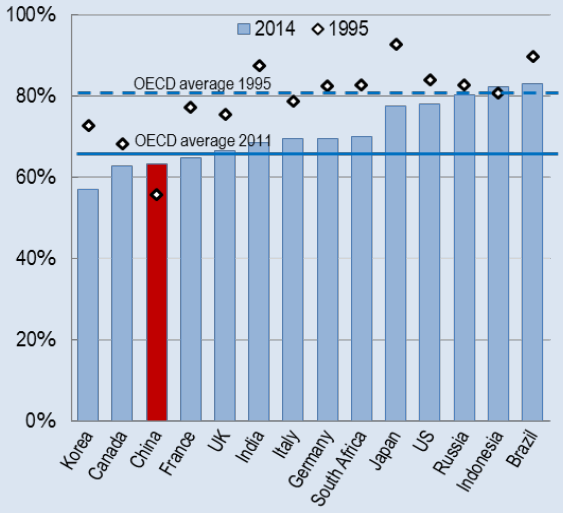
1.2. Moving up the value chain

China became the world's largest exporter and the second largest importer of merchandise in 2012. It has made considerable progress in moving up the ladders of GVCs. A growing share of manufacture value added is now produced domestically, up from the lowest point of 48.9% in 2003 to 63.2% in 2014, the highest in two decades (OECD, 2017a). The gap with the OECD average has closed substantially – from 25.6 percentage points in 1995 to 3.3 percentage points in 2014 (Figure 3.A). Although this indicator alone does not fully gauge China's position along the value chain (as it is partly a function of economic size and degree of global integration), it does point towards signs of domestic upgrading, either through increased specialisation in higher value-added activities or domestic substitution for imported intermediate suppliers or both (OECD, 2015b). This trend is also confirmed in the declining importance of downstream processing services or of foreign-funded company exports, as Chinese firms are increasingly involved in the various and more sophisticated steps of the production process.

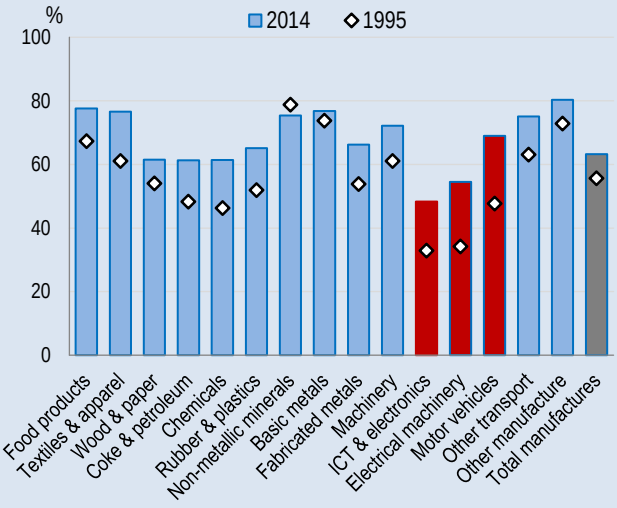
Furthermore, the growing domestic content share has occurred across nearly all manufacturing sectors, most significantly in three high-tech and medium-high-tech industries: ICT & electronics, Electrical machinery and Motor vehicles, with shares standing at 48.3%, 54.5% and 69.0% respectively in 2014, compared to 32.9%, 34.2% and 47.7% respectively in 1995 (Figure 3.B). These trends signal that China is moving from predominantly low-end, labour-intensive assembly to being a major exporter of high-tech manufactured goods. As confirmed by recent data, the share of high- and medium-high-tech manufacturing exports of China has nearly doubled between mid-1990s and 2014 (37% to 61%) (Figure 4.B). Since 2005, this increase has stabilised at levels around 61%, possibly suggesting growing challenges in further upgrading manufacture production and exports as new and emerging technologies – such as 3D printing – may shorten supply chains and lead to some "reshoring" of jobs and activities.

Figure 3. China's domestic value added of manufacturing exports has caught up fast with the OECD level and comes increasingly from high-tech sectors

A. Domestic content share of gross manufacturing exports
China, selected countries



B. Domestic value added share of gross manufacturing exports
China,1995, 2014



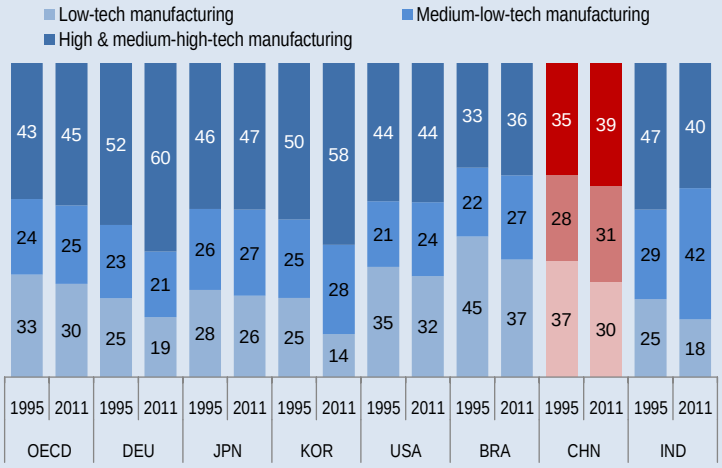
Source: OECD TiVA database, OECD TiVA Nowcast Estimates database.

Domestically, the underlying structure of China's manufacturing sector has also undergone profound changes, similar to the patterns of OECD and emerging economies. The high- and medium-high-tech sectors have gradually taken a larger share, accounting for 39% of total manufacturing value-added in 2011, albeit still lower than the shares more than a decade ago in early industrialised countries such as the United States (44%), Japan (46%), Korea (50%) and Germany (52%) (Figure 4.A). Since 2015, manufacturing in China has grown at an average annual pace of 8.1%, increasingly driven by the high- and medium-high-tech sectors. In contrast, growth has declined sharply in a range of traditional heavy industries, such as steel, cement, flat glass, aluminium smelting and shipbuilding that are experiencing excess capacity as a result of over-investment in pre-crisis boom years and of post-crisis stimulus measures.

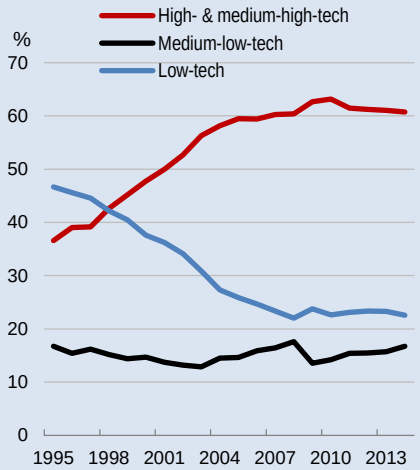
As China's manufacturing sector becomes more centred on high-tech and R&D-intensive industries, the share of employment in these sectors has grown from less than 25% in the early 1990s to about 35% in recent years (Figure 4.C). A similar trend is observed in the OECD area, where a steadily growing share of manufacturing employment has come from R&D-intensive industries, such as chemicals, machinery and transport equipment.

Figure 4. China is moving upward in the value-chain

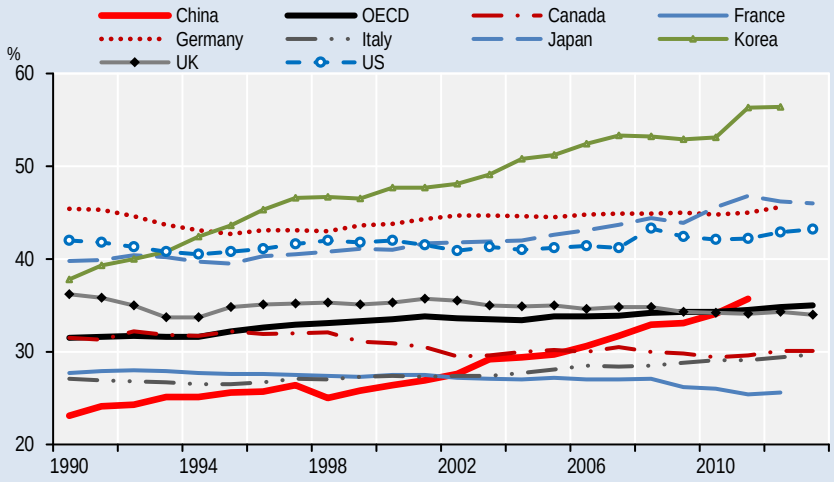
A. Manufacturing by technological intensity
% of total manufacturing value added by country, 1995, 2011



B. Exports of manufactured goods by technological intensity, 1995-2014



C. Employment in R&D-intensive manufacturing industries is growing



Note: The classification of sectors is based on the OECD methodology of classifying manufacturing industries into categories based on their R&D intensities. The methodology can be found at https://www.oecd.org/sti/ind/48350231.pdf. For ease of comparison, high-technology and medium-high-technology industries are merged into one category in this report. Other industry refers to mining, energy and construction; other services refer to community, social and personal services.

Source: OECD TiVA database; OECD TiVA Nowcast Estimates database; OECD (2015a).

Compared with other large emerging economies, the emergence of new sectors in China did not come at the expense of the traditional sectors. The country's strong economic growth was achieved through a combination of an increased supply of production factors – more labour, capital and natural resources – together with sustained growth of total factor productivity (OECD, 2013). China has used a wide range of policy tools, combining progressive opening to external competition with the creation of a better regulatory framework and business environment for domestic companies. A string of reforms including the restructuring of the banking sector, extensive price liberalisation, dismantling

of trade barriers and increased flexibility in the labour market have resulted in increased access to production factors (OECD 2002). Moreover, pro-active industrial policies have played a significant role. Typical industrial measures have consisted in priority sector development programmes, concessionary financing and preferential allocation of land, and government-guided mergers and acquisitions.

1.3. Innovation as an engine for growth

Besides a favourable policy environment and a series of structural reforms aimed at enhancing efficiency and market dynamics, China's upgrading along the value chains has been increasingly driven by innovation. Investment in science, technology and innovation has increased steadily over the past decades. In 2014, China surpassed Japan and the European Union to become the second largest performer of R&D, accounting for slightly less than a quarter of global gross expenditure on R&D (GERD). Numerous science and technology programmes and foundations were established to enhance the country's scientific and technological strength and support broad-based economic and social development (OECD, 2016). The number of patents has surged alongside the rise in R&D spending: in 2015, China's patent filings exceeded one million, making up over a third of the world stock. Nevertheless, new patents' impact on productivity has declined, reflecting quality and relevance issues. Most patents are utility or design patents, not genuine inventions, and only a fraction are registered overseas as triadic patents, lagging behind most OECD and many emerging economies (OECD, 2017b).

More broadly, China has launched a swathe of initiatives and roadmaps, such as *Made in China 2025* and *Internet Plus*, to harness the potential of new technologies, particularly digital technologies, new materials and processes that drive the Next Production Revolution. Many Chinese companies have made great advances in creating and using new production technologies. China now has the world's largest stock of industrial robots and the world's largest number of connections of machine-to-machine SIM cards, and in 2015 was already the third largest issuer of 3D printing patents (OECD, 2017c). Special attention has also been given to support the development of seed, start-up and growth-oriented small and medium-sized enterprises, through the establishment of a national SME development fund in 2015 with a budget of USD 17 billion PPP (CNY 60 billion).

While progress has been rapid, further upgrading in manufacturing faces complex challenges. In many sectors, extensive gaps exist in basic manufacturing capabilities, such as mastery of key processing technologies, the ability to produce necessary materials, and management and digital capabilities. Challenges also exist in commercialising research, encouraging greater researcher collaboration, improving patent quality and enforcing protection of intellectual property rights. The 2017 OECD *Economic Survey of China* recommends that support for research and development, which at present is overly concentrated on high-tech industries, be broadened to a wider range of sectors to boost innovation across the economy and maintain sustainable growth.

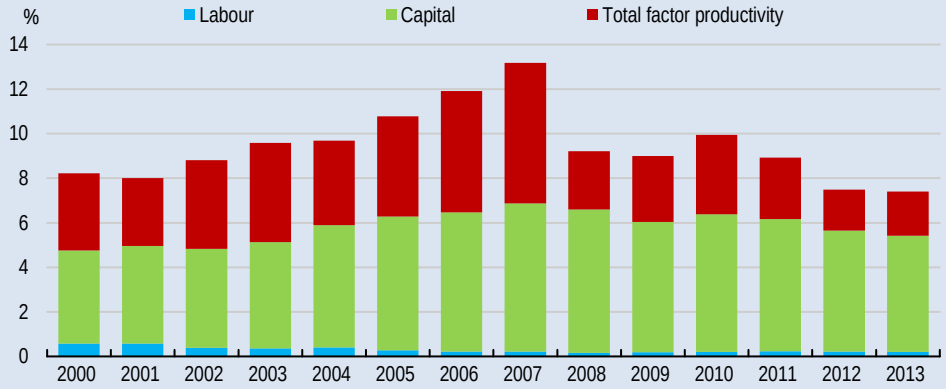
1.4. Industrial expansion and productivity growth

China's economic growth since the 2000s has been increasingly fuelled by the accumulation of factor inputs. The comparative advantage it enjoyed in the manufacturing sector – from low labour costs and access to inputs – has been substantially eroded. On the supply side, investments in capital stock have continued to provide the main means for reaching GDP growth targets, particularly since the global financial crisis. The efficiency

of these investments however has fallen, possibly due to overinvestment and misallocation of resources. As the Chinese economy is experiencing problems of overcapacity in some sectors, the contribution of multi-factor productivity (MFP) to growth has decreased in recent years. This is similar to the developments observed in many OECD countries: the contribution of MFP to GDP growth has flagged from the peak level of 48% in 2007 to less than 30% in 2013 (Figure 5).

In light of China's ambitions to improve both environmental and economic outcomes, enhancing productivity will be instrumental to maintain the competitiveness of the Chinese manufacturing and sustain growth prospects in the long term. Productivity improvements will need to increasingly rely on innovation and entrepreneurship. There is a growing recognition in China that innovation should not be confined to emerging and frontier-technology projects, as is the case currently, and that more should be done to improve the efficiency and environmental performance of traditional manufacturing through R&D and technology developments (OECD, 2017d).

Figure 5. Productivity growth has been declining since the crisis



Source: OECD (2017b)

1.5. Environmental implications

Becoming the factory of the world has intensified pressures on China's environment. Industry is a major source of pollution, greenhouse gas emissions and waste generation which exert an increasingly adverse impact on human health and the environment. These impacts impose significant costs on the economy and are a growing source of public concern. Industry is also a major user of energy, materials and other natural resources. The manner in which these resources are used affects short-term internal costs, determines their external costs, and affects long-term prospects for sustainability throughout the economy and supply chains.

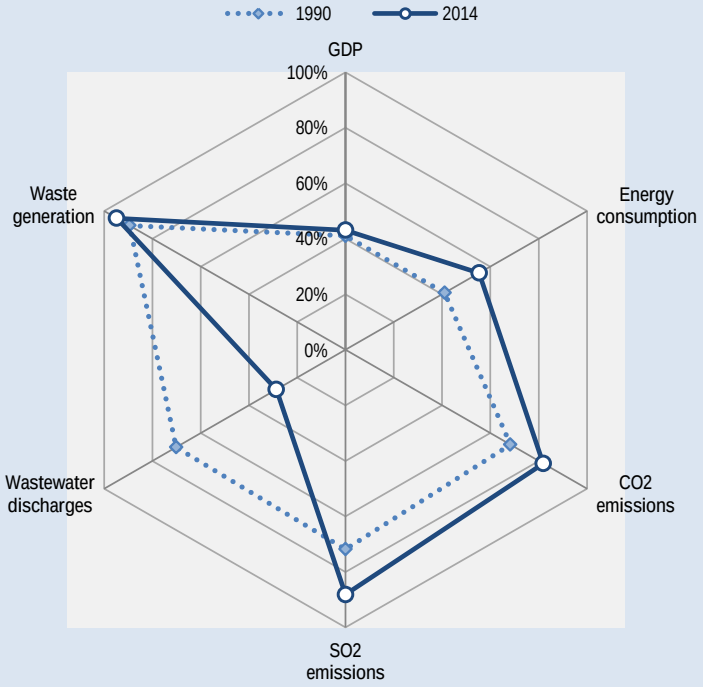
After the turn of the century, environmental pressures from the rapid industrial expansion became a major policy issue. Air and water pollution and soil degradation have reached alarming levels. China's energy consumption per unit of GDP is among the highest in the set of OECD and BRIICS economies. It is also the world's largest emitter of CO_2 emissions since 2006 and is the source of enormous quantities of a range of pollutants. Industry is at the origin of many of these pressures. For example, industry generates more than 80% of

the country's waste and CO_2 and SOx emissions (Figure 6, see also page 25). While legal requirements have become more stringent, weak enforcement has meant that the environmental impact of Chinese industry is greater than it should have been.

The build-up of excess capacity in several energy-intensive and highly polluting industries constitutes an additional threat to the environment. It creates incentives for scaling-up production, especially as most of these sectors exhibit high economies of scale. Excess capacity drains financial resources from companies that could be used to finance innovation and investment in technologies that improve the environmental and resource efficiency of production. It also distorts competition and, while at sector level it increases pressure for sector restructuring, at company level it acts as a barrier to restructuring, particularly when the excess capacity is not fully or mostly amortised.

Figure 6. Environmental profile of the Chinese industry*

Contribution by industry to selected environmental pressures, 1990, 2014



Note: *Industry refers to the mining and quarrying, manufacturing and energy sectors. Data on the share of industry in waste generation are overestimated, since waste from other sources only covers urban areas.

Source: varied issues of Report on the State of the Environment in China, Environmental Data Handbook, and China Statistical Yearbook on Environment; IEA (World Energy Balances database and CO2 Emission from Fuel Combustion database).

Against this backdrop, industrial restructuring and upgrading for greener growth will require not only a quicker exit of unprofitable and polluting firms from the ailing sectors, but also the reallocation of resources to greener, more productive and higher value-added segments of the economy. The development of a cleaner and more productive industry through the restructuring and upgrading of the traditional sectors and through harnessing the opportunities provided by the Next Production Revolution offers an attractive pathway to facilitate China's transition to a more balanced, sustainable and higher productivity pattern of development.

2. China's economy and industry in a green growth perspective

This section assesses China's position vis-à-vis green growth through the lens of the OECD green growth measurement framework and indicators, which monitor progress with respect to four objectives: establishing a low carbon and resource efficient economy and improving its productivity, maintaining the natural asset base, improving people's quality of life, and creating economic opportunities from green growth. Particular attention was given to developments in the environmental and resource productivity of the Chinese economy and the role of environmental policies. The indicators presented are based on data from official sources in China, and on data from the OECD and other international organisations (Box 1).

2.1. Overview of China's position with respect to green growth

China's rapid industrial expansion has spurred high rates of economic growth, but has also involved over-investment and misallocation of financial resources, excessive exploitation of natural resources and degradation of environmental quality. When reviewing China's position with respect to green growth using a small set of GG indicators, a mixed picture emerges (Figure 7):

- On the one hand, significant progress has been achieved as regards energy and carbon productivity. Economic instruments such as environmentally related taxation are increasingly used, and policies concerning air and climate issues have become more stringent and started converging with those used in OECD countries. China has also succeeded in decoupling some of its environmental pressures (i.e. traditional air pollutants such as SOx and NOx) from economic growth much faster than OECD countries and at an earlier stage of economic development.
- On the other hand, progress achieved has tended to be overwhelmed by the steady growth of economic activity and industrial production. Pressures exerted on the environment are high and growing, and single factor productivity levels for carbon, energy and materials are low and lag behind those of OECD countries and of other emerging economies.

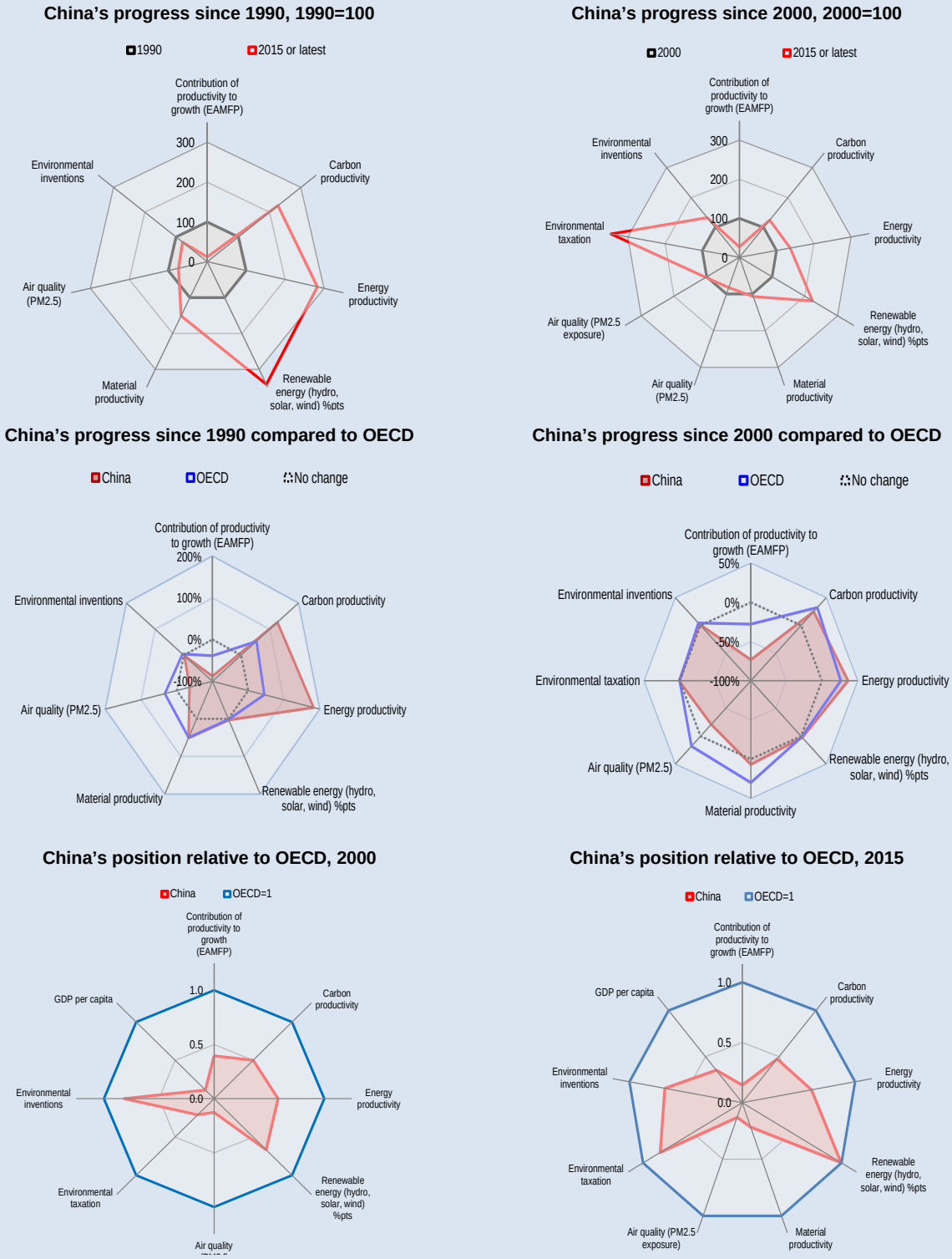
To generate USD 1ºº00 of GDP:

China	uses 180 ktoe of primary energy	and 1 930 kg of materials other than energy,	and emits 540 kg of CO2 from energy use
BRIIS countries	use 130 ktoe of primary energy	and 960 kg of materials other than energy,	and emit 300 kg of CO2 from energy use
OECD countries	use 110 ktoe of primary energy	and 420 kg of materials other than energy,	and emit 260 kg of CO2 from energy use

*All figures are rounded.

Overall, productivity gains have played a modest role in spurring economic growth in China, even more so when accounting for environmental factors (use of subsoil assets, air pollution). Productivity gains over 1991-2013 (in terms of environmentally adjusted MFP) contributed to only 26% of growth in China, compared to over 60% in many OECD countries.

Figure 7. Overview of China's progress towards green growth



Source: Authors' calculations based on OECD Green Growth Indicators database.

Box 1. China's environmental information system and indicators

Good quality and reliable environmental information is the basis for enhancing the effectiveness of environmental policy. China began developing its environmental information system in the mid-1980s. Between 2006 and 2010, a three-tier governance system was established, consisting of national, provincial and municipal level institutions. Infrastructure for the information network was built, covering all environmental protection bureaus across the country. A number of systems were deployed to monitor environmental quality and pollution sources, manage environmental emergencies and complaints, collect pollution levies and evaluate and approve construction projects. As a result, a wealth of data are now available at national, provincial, municipal and industry levels, and the coverage ranges across areas of environmental quality, pollution, ecosystems, nuclear and radiation safety, and environmental management. The main institutions and agencies involved in environmental information include the Ministry of Environmental Protection and its affiliate centres and research institutes such as the Chinese Academy of Environmental Planning and the Environmental Monitoring Center, the National Bureau of Statistics (official statistics in the areas of energy, resources and environmental accounting), the Ministry of Water and Resources, etc.. Overall, more than ten ministries and agencies are involved in data collection and monitoring. There are sometimes overlaps among the portfolios of these ministries and agencies, and the sharing of information does not always take place.

The 13th Five-Year Plan identified improving environmental quality as the core objective of environmental policy and governance for the next five years. Attention has also been given to information technology and modern instruments, such as Big Data, for the provision of higher quality and real-time data. The 2015 Plan on Environmental Monitoring Network Construction and the 2016 Action Plan on Quality Management for Environmental Monitoring, aim to enhance the reliability, accuracy and comparability of environmental data through better institutional setting and technical standards. By 2020, a national vertical system for monitoring and supervising ambient, surface water and soil quality will be established. The Plans mark some major developments in the management of environmental information. Responsibility for environmental quality monitoring will be centralised, shifting to a model of "who evaluates, monitors". As a result, the China National Environmental Monitoring Centre (affiliated to the Ministry of Environmental Protection) now receives first-hand data and directly manages 1436 air quality monitoring stations across the country. This is an important change from the previous system, where sub-national authorities were both "judge and jury". The Plans also propose the introduction of several innovative approaches, including encouraging third parties to enter the quality supervision system, promoting information sharing among various ministries and agencies, and integrating on-line monitoring systems to strengthen environmental enforcement.

China has also been broadening the performance evaluation system for senior subnational government officials, centred on growth in GDP, to include environmental targets and indicators drawing on China's comprehensive set of green development and ecological civilisation indicators. In addition, a composite green development index has been elaborated to support the evaluation. The integration of environmental aspects in the assessment of the career prospects and progression of senior officials provides a basis for strengthening the oversight of sub-national governments' progress towards green growth, while enhancing their accountability through "race to the top" competition. The environmental performance of sub-national authorities is seen as key to China's environmental performance.

2.2. The natural asset base of the Chinese economy

China has a vast territory with a rich endowment of natural resources and a great diversity of land resources. It has abundant hydropower resources, and ranks first in the world with 660 million kW of exploitable installed capacity. Geographically, it is the world's third largest country, occupying 7% of the global land area, following Russia and Canada. China has proven reserves of almost all kinds of metallic mineral resources that have so far been discovered worldwide, and is home to the world's largest reserves of tungsten, tin, antimony, rare earth, tantalum and titanium.

When comparing this wealth of natural resources with the size of China's population, a different picture emerges: China appears as one of the world's most *resource-scarce* countries. This is particularly true as regards renewable natural resources, which are key to food supply and biodiversity. China's per capita endowment of these resources is less than the world average: freshwater (25%), forest (40%), arable land (25%) and grassland resources (50%).

Another feature of China's natural resource endowment is its extremely *uneven distribution* across the territory. The Eastern part of the country produces more than 60% of the national GDP, with merely 14% of the total land area and less than one third of other major types of resources (e.g. water, forest and minerals). Mineral resources are often concentrated in areas far away from the economic centres, which entails significant transportation costs and pressures on the environment. China has been implementing inter-regional allocation of resources since ancient times, and the nation-wide infrastructure network is being consolidated for a more effective deployment and use of unevenly distributed resources across the country.

Another case in point is water resources, which are concentrated in the Western and Southern parts of the country. In other parts, particularly in the Northeast, high water demand from urban areas, industry and agriculture, combined with high pollution, low precipitations, and insufficient access to surface water could become a constraint for economic development. In 2012, the government started to implement the "most stringent water resources management system", and committed to capping total water consumption at levels below 670 billion cubic metres by the end of the 13th Five-Year Plan period. Efforts are also being made to better plan industrial production and urban development based on the amount of available water resources, and to impose stricter control over industrial development and water quotas in regions affected by water scarcity.

As the Chinese economy is still growing at a medium to high pace, and population growth has not yet reached its peak, demand for natural resources is projected to remain strong for many years ahead. The economy has in the past already experienced episodes of resource shortages, in part due to the predominance of resource-intensive industries and the over-reliance on certain types of resources associated with a "predatory" exploitation. As a result, arable land suffers from erosion and degradation; proven reserves of major mineral commodities such as oil, natural gas, iron, copper, lead and uranium are low or of poor quality, and industrial production is becoming more and more dependent on overseas supplies.

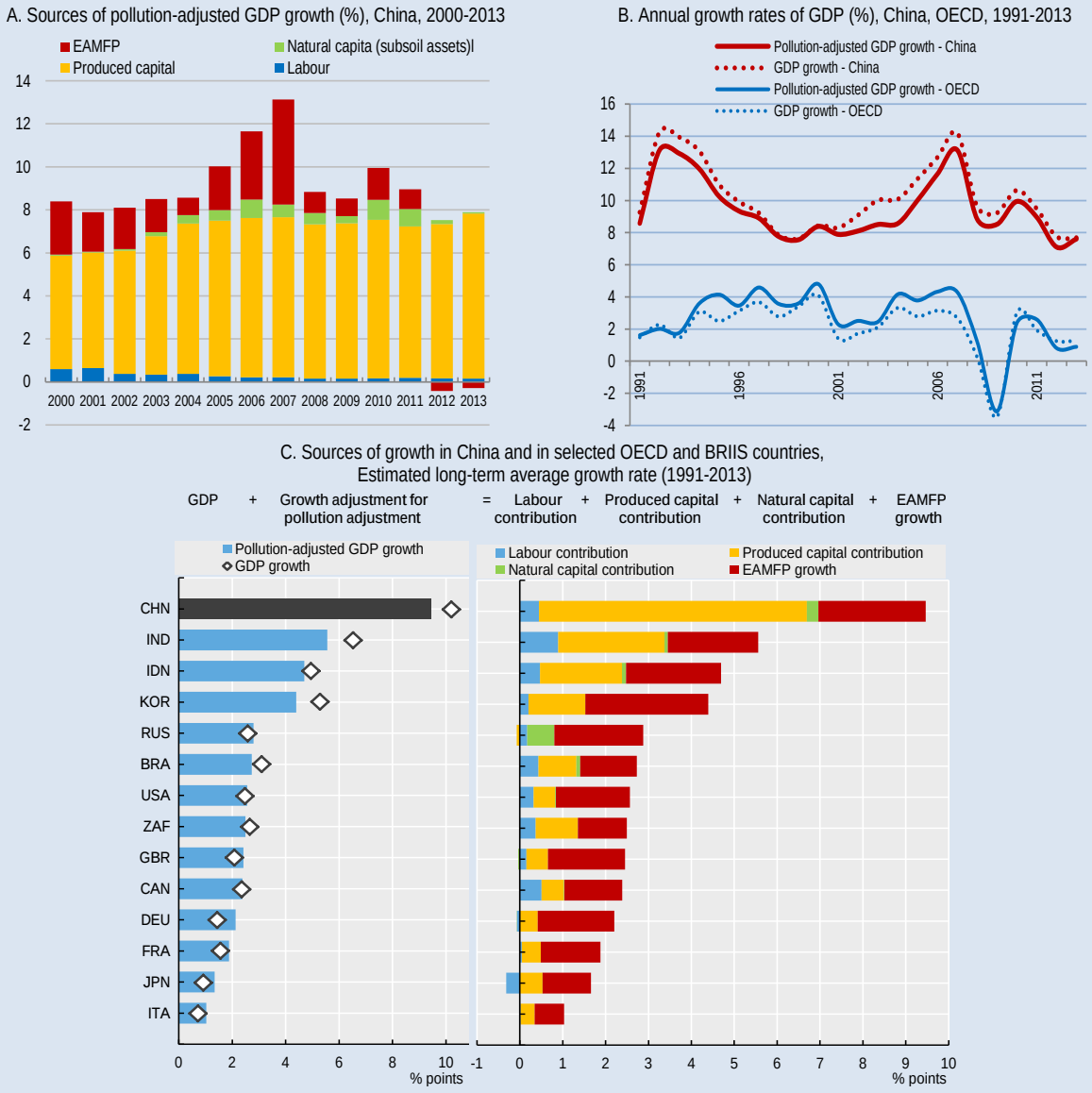
In 2011, China relied more than half of its supplies of oil, gas, iron ore, copper, lead and zinc on imports. The country consumed 12% of the world's metals in 2000, up to nearly half by 2014. A small net coal exporter until 2008, China became the world's largest coal importer in 2011. It is also the world's largest importer of copper (35% of the global imports), manganese (60%), and aluminium and iron ore (both 65%)[7]. Since 2012, China has been the second largest food importer in the world (behind the US), and its share in global food imports has nearly quadrupled between 2003 and 2016 (World Bank, WDI database).

[7] Minerals Council of Australia (2015), *China, minerals and energy and the China-Australia Free Trade Agreement (ChAFTA)*, Trading Nation Consulting; www.minerals.org.au

2.3. The environmental and resource productivity of the Chinese economy

China's strong economic growth and the predominance of resource- and pollution-intensive industries are directly linked to rising environmental pressures, growing consumption of energy and raw materials, and an increasing dependence on imports for some commodities, including food and minerals. China has begun to decouple some environmental pressures from economic growth, but the increasing scale of pollution has outweighed emission reductions and improvements in resource efficiency. As a result, the China's environmental and resource productivity remains low and is a key factor contributing to its pressing environmental challenges.

Figure 8. China has been drawing heavily on produced and natural capital to generate growth at the expense of the environment



Note: Negative values mean that the contribution of input to output growth has been decreasing over the period.
Source: OECD Environmentally Adjusted Multifactor Productivity database.

2.3.1. Multi-factor productivity and other sources of growth

OECD estimates of environmentally adjusted multi-factor productivity (EAMFP) growth confirm China's reliance on natural resources and ecosystem services to fuel economic growth, and the costs imposed on growth by high levels of air and greenhouse gas emissions. While growth in many OECD countries over the past 20 years has been generated almost exclusively through productivity gains, China has drawn to a much greater extent on increased utilisation of labour, produced capital and natural capital to generate additional growth (Cárdenas et al. 2016) (Figure 8). EAMFP growth, that is the share of growth (after adjustment for pollution generation) that is not explained by the use of labour, produced capital and natural resources, has weakened since 2008, and to a greater extent than the traditional measure of multifactor productivity. It is estimated that less than 30% of China's (pollution-adjusted) growth performance over 1991-2013 can be attributed to rising productivity, compared to nearly 60% on average in OECD countries.

While this might have had some short-term benefits in terms of lower production costs, it has generated higher external costs, which can impinge on the sustainability of economic development and on future well-being. If account is taken of environmental factors such as the generation or abatement of pollution (essentially emissions of air pollutants and GHG), China's GDP growth over the past two decades should be adjusted downward, indicating that economic growth has been achieved at the expense of environmental quality. On the contrary, in OECD countries where pollutant emissions have decreased over the last two decades, growth would be adjusted upward (Figure 8) to reflect the fact that scarce resource were invested in pollution abatement rather than to the production of material goods.

2.3.2. Carbon productivity

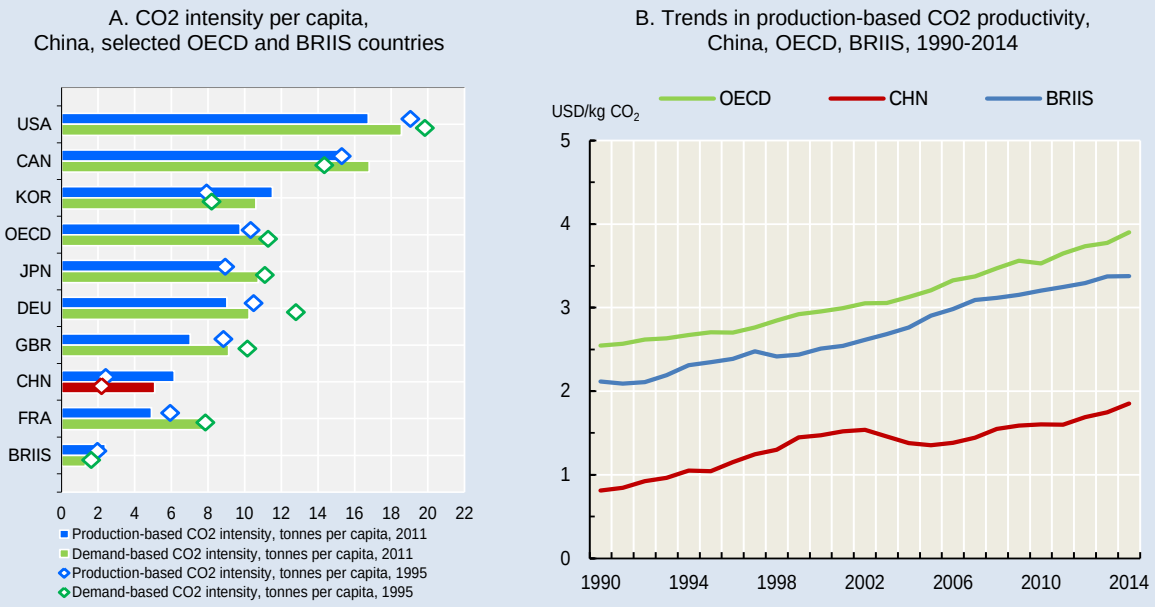
China has been the world's largest emitter of carbon dioxide since 2006, generating more CO_2 emissions than the United States and the European Union combined. In 2015, it accounted for 28% of global CO_2 emissions from fuel combustion (2018 IEA data) compared to 10% in 1990. Almost half of these emissions stem from the generation of electricity and heat that still largely depend on coal. Carbon emission levels and per capita intensities have grown rapidly in China, particularly since its entry to the WTO, while they have remained relatively steady in OECD and BRIIS countries (Figure 9.A). As GDP per capita increases in China, its per capita carbon emissions (6.5 tonnes per person in 2014) are likely to continue to rise and converge with the per capita levels in OECD countries (9.4 tonnes per person in 2014).

In terms of carbon emitted to satisfy domestic final demand (i.e. the net amounts of carbon from domestic production plus the carbon embodied in imports and minus the carbon embodied in exports), the amounts emitted per person are lower in China than in OECD countries and similar to those in the BRIIS economies. It reflects changing international trade patterns and the off-shoring of production from OECD countries to China and BRIIS countries.

China's carbon productivity (GDP generated per unit of energy-related CO_2 emissions) more than doubled during the 1990-2014 period, but still remains below the OECD average (Figure 9.B). In 2014, China produced USD 1853 of economic value per tonne of CO_2 emitted, which is less than half the OECD average of USD 3910 per tonne. This is partly related to different economic structures, with China having a smaller service sector and larger, more energy-intensive, manufacturing sector compared to OECD countries, and partly to China's heavy reliance of coal and other fossil fuels. The picture is similar when considering demand-based emissions of CO2, but with slightly higher productivity ratios.

Progress with CO_2 emissions from energy use in China remains below that of many developed countries, and many opportunities for further progress exist. Following the ratification of the Paris Climate agreement in September 2016, China has committed to lowering its carbon emissions by 60-65% per unit of GDP from the 2005 level and to peaking its carbon emissions by 2030. The 13th Five Year Plan (2016-20) aims at reducing, by 2020, CO_2 intensity per unit of GDP by at least 40% from its 2005 level, including through a nationwide cap-and-trade carbon emissions system that rolled out by the end of 2017.

Figure 9. Carbon productivity is improving but remains low



Source: OECD-IEA

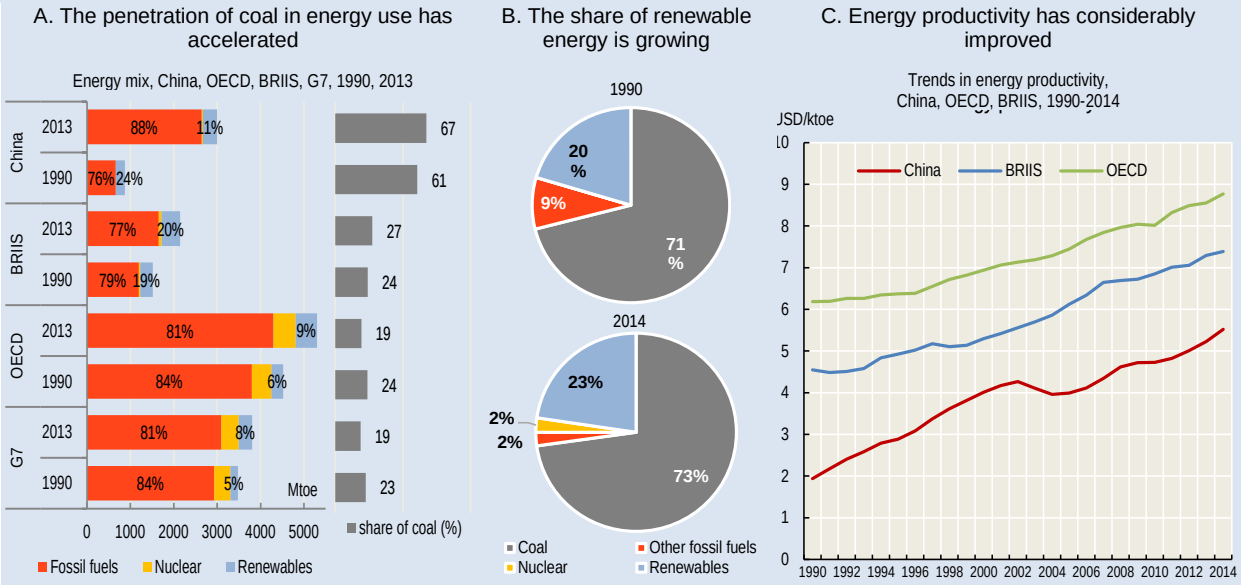
2.3.3. Energy productivity and renewables

The energy productivity of the Chinese economy has improved considerably since 1990, more than in OECD and BRIIS countries over the same period. This is due to a combination of factors, including the very high growth rates of GDP, structural changes within the economy as well as technological advancements. These improvements were accompanied by the development and use of cleaner fuels and renewable energy sources. China has become the world's largest investor in renewable energy since 2012, totalling USD 102.9 billion in 2015, or 36% of global investment in renewables (UNEP, 2016). The mix of renewables in primary energy supply has diversified. Solar, wind and hydropower increased more than ten-fold during 1990-2014, while traditional use of biomass for cooking and heating, which can exert significant pressures on human health and ecosystems, considerably reduced. The use of hydropower in electricity generation increased eight-fold during the same period, while the use of solar energy has been growing exponentially since 2010. Coal nevertheless continues to dominate the country's energy supply and power generation. Its penetration has even accelerated over the past ten years: it is abundant domestically, can be mined inexpensively and used easily in place of other

fuels. Moreover, some industries have long benefited from preferential energy prices discouraging energy conservation (Figure 10).

Today, China still generates much lower economic value (in terms of GDP) per unit of energy consumed than the OECD countries and BRIIS economies. This indicates untapped opportunities for efficiency gains, which are vital to the shift to a low-carbon economy. To rebalance the energy mix and reduce its heavy reliance on coal over the medium term, the country has recently set caps on coal consumption at the level of 4.1 billion tonnes in 2020. Targets for further reducing energy consumption intensity per unit of GDP and increasing the share of non-fossil energy to 15% by 2020 are set in the 13th Five Year Plan.

Figure 10. China's energy mix is slowly diversifying, but consumption remains high and coal dominates



Source: OECD-IEA.

2.3.4. Material productivity and waste

China's growth model, driven by increasing factor inputs, has led to increasing consumption of natural resources and continued dependence on energy and materials to fuel economic expansion. In 2015, China accounted for 17% of global GDP (at current PPPs, international dollars) but consumed 23% of world energy[8], over 50% of cement[9] and 45% of steel products[10]. In 2012, China's non-energy material productivity - GDP generated per unit of domestic use of materials other than energy - was half the level of the BRIIS economies, 22% of the OECD average, and less than 10% of the level of leading OECD countries such as Japan and the United Kingdom. As in many other countries, construction minerals dominate the materials mix (Figure 11).

8 BP Statistical Review of World Energy, June 2016

9 Global Cement Report, 12th edition.

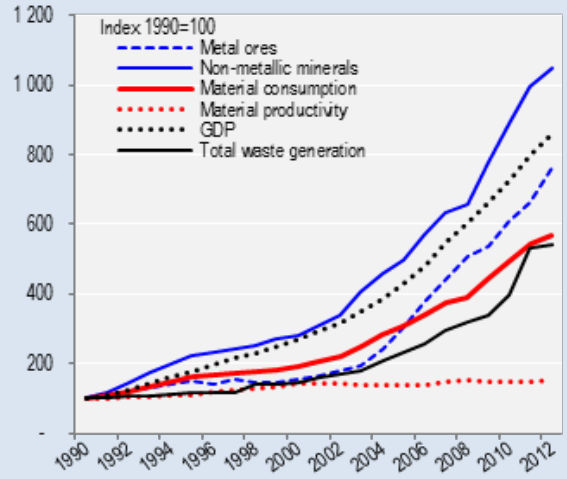
10 World Steel Association, Steel Statistical Yearbook 2016

The high and inefficient level of material resource consumption has also exacerbated the generation of waste and other types of residuals and pollutants. Waste generation has been growing in line with economic activity and material consumption; most of it comes from industrial processes and activities. Valuable materials contained in waste are thus lost to the economy if not recovered. Although the absolute volume of waste remains large, annual growth rates have significantly decreased in recent years compared to 2003-2010. As a result the generation intensity per unit of GDP (2010 prices) was 600 kg per USD1000 in 2014, half the level in 1990. On the other hand, on average, Chinese citizens each generated around 2.5 tonnes of waste between 2011 and 2014, more than four times the amounts generated in the early 1990s.

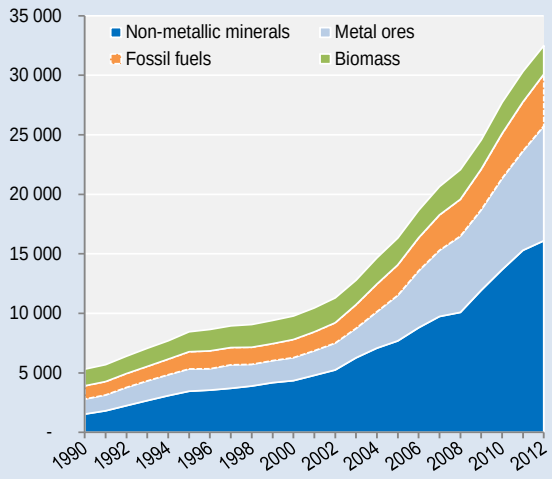
Figure 11. Non-energy material productivity and materials mix

A. Material consumption increases in line with economic growth

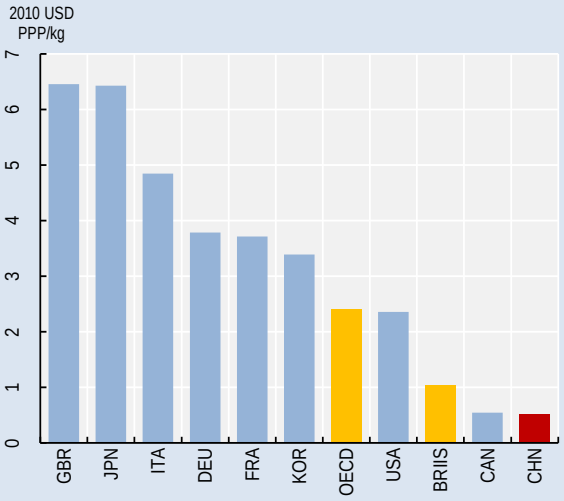
Decoupling trends and material productivity



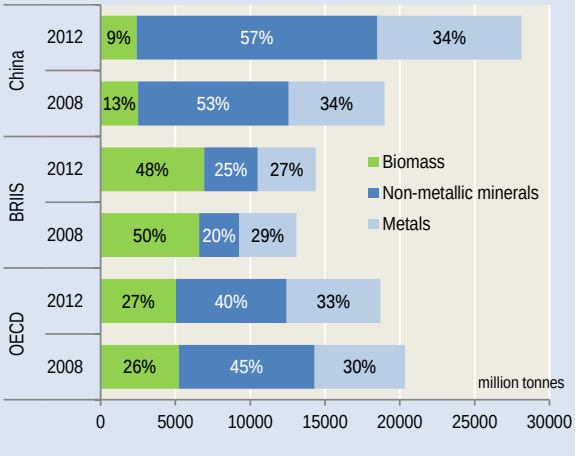
Materials mix



B. Non-energy material productivity (GDP/DMC) is low, but comparable to some other resource rich countries, 2012



C. Construction minerals dominate the materials mix in consumption



Note: OECD estimates based on OECD Material Flow data and the UNEP Material Flow database (2015)

Source: OECD, UNEP

2.3.5. Air pollution and human health

Air emissions

The pace and composition of China's economic development has resulted in high levels of a range of air pollutants. While pollution control measures put in place since the turn of the century have shown first results, the increasing scale of pollution has long outweighed marginal reductions in many emissions. Nevertheless, China has begun to decouple some traditional air emissions from economic growth. It achieved absolute decoupling of SO_2 and NOx emissions at a lower level of GDP per capita and when the share of services in the economy was lower than in advanced OECD countries (Figure 12, Figure 13). Decoupling also occurred at relatively lower levels of emission intensities. In addition, some water pollutants such as ammonia nitrogen have been declining since the early 2000s. This is explained by the cost of abatement options that have become available at competitive costs only more recently. Technological leapfrogging and policy convergence, perhaps linked to increased public demand for improved environmental conditions, may also have contributed. It is expected that the next five years will witness peaking or absolute decoupling of other key pollutants. One of the challenges will be to maintain and even increase the downward trends after the peak years.

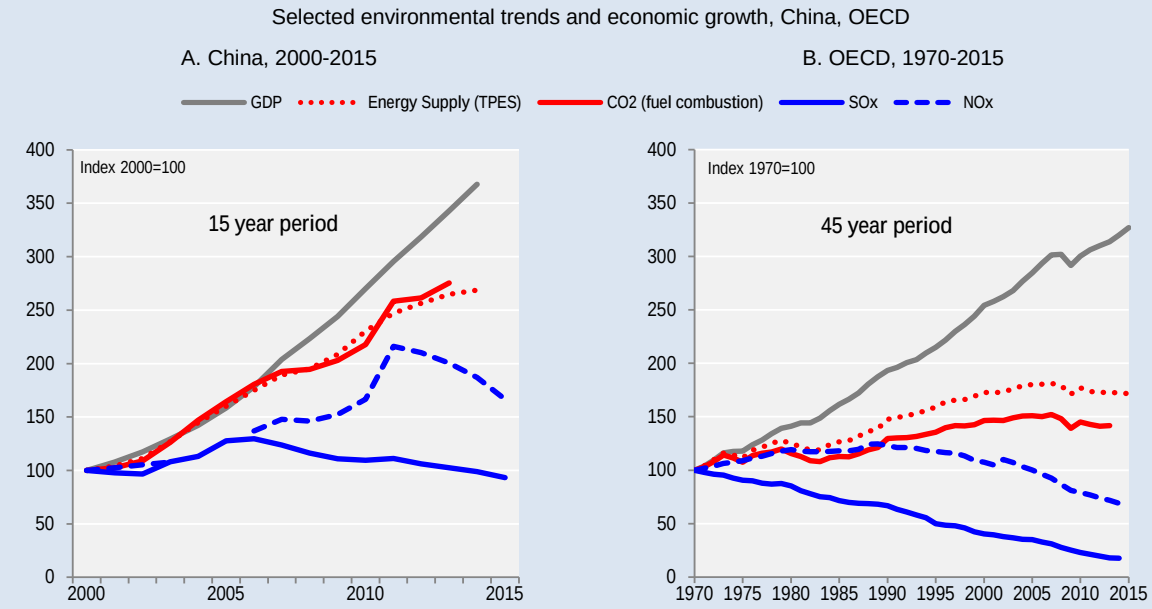
SOx emissions peaked in 2006, at almost double the level of 1980. This followed an increase in emissions between 2003 and 2006 due to rising consumption of energy (particularly coal) associated with a new wave of economic expansion (following China's entry to the WTO in 2001) as well as rapid industrialisation and urbanisation.

NOx emissions seem to have peaked in 2011[11]. This followed a sharp increase between 2006 and 2011 due to the continued rise in energy consumption (particularly coal) associated with the policy stimulus to economic growth after the global financial crisis, increasing motor vehicle stocks and emissions from household sources. The surge in emissions in 2010-2011 can also be explained by a change in the scope of emission sources that were monitored; NOx emissions from motor vehicles and centralised pollution control facilities were included in the inventory. The declining trend after 2012 is partly due to the widespread installation of denitrification equipment in coal-fired power plants, as required in the 12th Five Year Plan; to lower demand for energy (particularly coal) associated with an economic slowdown; and to a change in the scope of "above-scale industrial enterprises" covered in the emissions inventory (the threshold of annual income increased from 5 to 20 million yuan). Whether this declining trend can be maintained remains to be seen in the years to come.

[11] Official NOx data for China only exist since 2006; data prior to 2006 are either academic estimates or drawn from China's replies to a questionnaire supporting the 2007 OECD *Environmental Performance Review of China* combined with OECD estimates prepared in collaboration with the MEP.

Figure 12. China decoupled some environmental pressures faster than OECD countries

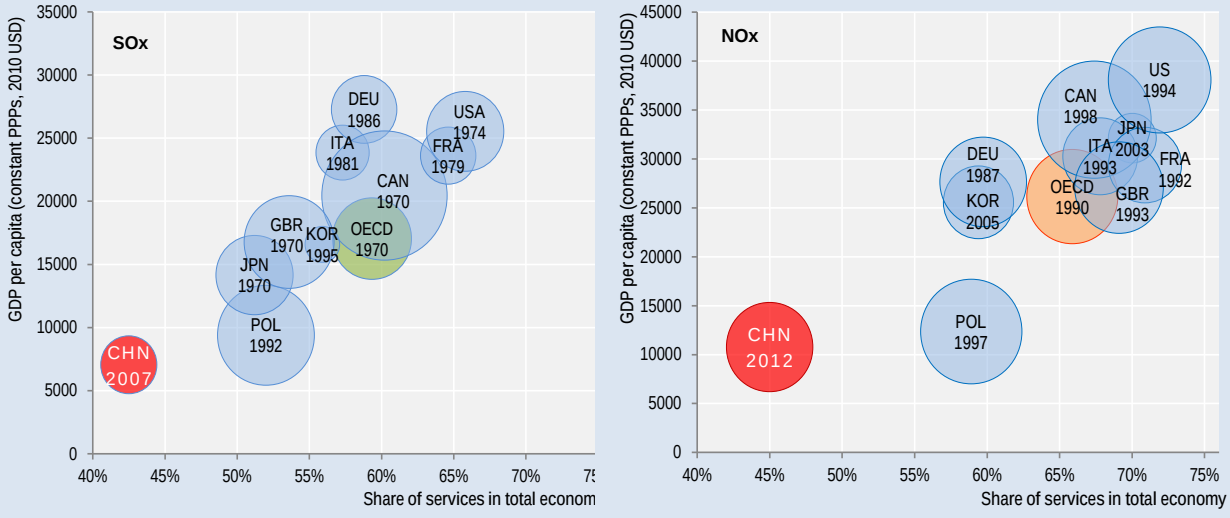
Selected environmental trends and economic growth, China, OECD



Source: OECD, IEA, Ministry of Ecology and Environment (former known as Ministry of Environmental Protection, MEP)

Figure 13. Decoupling of SOx and NOx emissions first occurred at a lower level of economic development than in OECD countries

Positioning of countries when absolute decoupling of environmental pressure first occurred



Note: The size of the bubbles represents the level of SOx and NOx intensity of the economy when absolute decoupling first occurred.

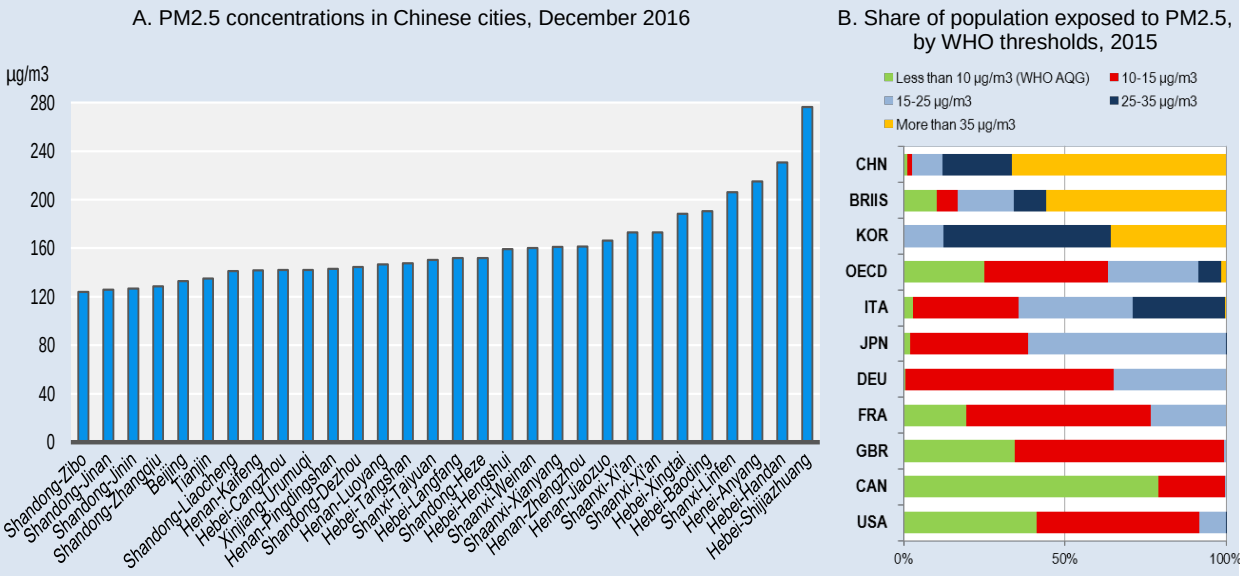
Source: OECD calculations based on original data provided by countries. Adjustments are applied when connecting previous series of pollution emissions statistics with the latest updates, but the calculation methods used to produce the data may differ across series and thus not directly comparable.

Human exposure to air pollution

Despite important reductions in some air emissions, emission levels and ambient concentrations remain high with adverse effects on human health and the environment. This is particularly the case for emissions of fine particulates ($PM_{2.5}$) and other air pollutants such as NOx and ozone (O_3). Pollution by $PM_{2.5}$ is particularly worrying with 66% of China's residents being exposed to extremely high levels of air pollution by fine particulates that significantly exceed the guidelines of the World Health Organisation (WHO). In 2016, less than a quarter of the country's 338 cities at and above the prefecture level, met the air quality standards (for SO_2, NO_2, PM_{10}, $PM_{2.5}$, CO and O_3) introduced in 2013 and fully applied since 2015.

Air pollution is particularly severe in the northern regions of China, especially during winter months. Hebei province, which has a large steel industry, ranks highest among provinces in terms of PM 2.5 concentrations (in addition to Henan and the municipalities of Beijing and Tianjin). In December 2016, Hebei's provincial capital Shijiazhuang was the most polluted city (its steel mills were ordered to stop production for the last two months of 2016 to reduce pollution) and seven other cities in the province feature among the 30 most polluted in China (Figure 14).

Figure 14. Air pollution by fine particulates is high and population exposure raises concerns



Source: AQIStudy (China Air Quality Online Monitoring Platform), OECD (2017), "Air quality and health: Exposure to PM2.5 fine particles - countries and regions", OECD Environment Statistics (database). http://dx.doi.org/10.1787/96171c76-en

2.4. The environmental and resource productivity of the Chinese industry

The characteristics of China's industry play an important role in the increasing deterioration of the environment and constrain opportunities to green the economy. The sheer scale of industrial production, the preponderance of heavy industry and of resource and pollution-intensive industrial processes, have intensified the impact of the industry on the environment and human health. Many industrial processes rely heavily on coal for power

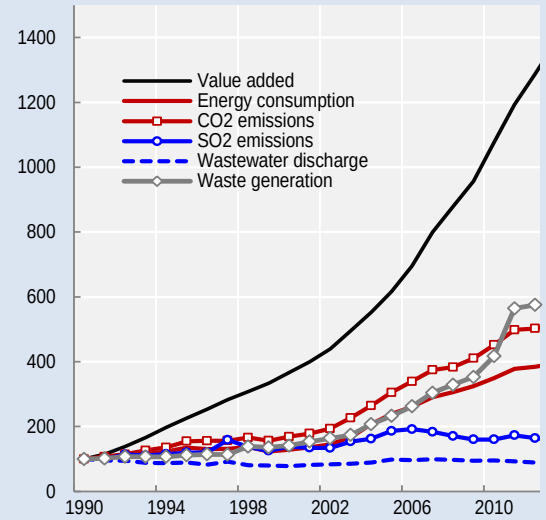
generation, which exacerbates carbon and other emissions and their effects on the environment and human health.

Energy-intensive manufacturing industries, such as basic metals (iron and steel, aluminium), non-metallic minerals (e.g. cement), chemicals and oil processing, have grown at a rapid pace, although their share in total industrial value added has remained steady at above 25% in the past two decades. These industries have exerted significant pressures on the environment by way of pollutants and greenhouse gas emissions (e.g. CO_2, SOx, NOx, and waste water) and natural resource use (e.g. material consumption, water use, waste generation). As in many OECD countries (OECD, 2017e), a small number of industries in China account for the bulk of CO_2 and air pollutant emissions, which is disproportionate compared to their weight in the economy. For instance, in 2011, basic metals (including iron and steel, aluminium), chemicals (including crude oil refinery) and non-metallic minerals (including cement) contributed to 82% of total CO_2 emissions from manufacturing industries but less than 40% of total manufacturing value added (OECD TiVA data, 2017; IEA data, 2012). Other sectors, mostly with higher technological content, such as manufacturing of communication and electronic equipment, display the opposite patterns.

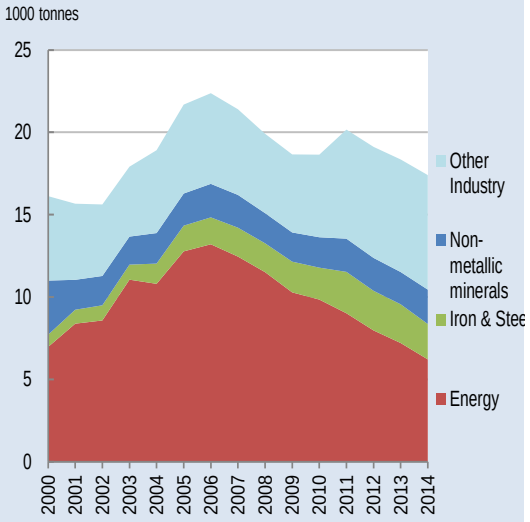
The 1990-2014 period saw a three-fold increase in energy consumption by industry (Figure 15.A). CO_2 emissions grew even more as a large share of the increased energy demand was met through coal-fired power generation, adding to the use of coal in industrial processes. Over the same period, the iron and steel industry more than doubled its share in national energy demand. In 2014, it accounted for 13.7% of total final energy consumption and almost 30% of the energy consumed by the manufacturing sector. Iron and steel generated more than two fifths of all CO_2 emissions from manufacturing industries in China, a share higher than the OECD (22.1%) and world (33.4%) averages. It also contributed to nearly two thirds of the CO_2 emissions generated by this sector globally.

Figure 15. Environmental profile of the Chinese industry*

A. Selected environmental trends in industry versus value added
Index 1990=100



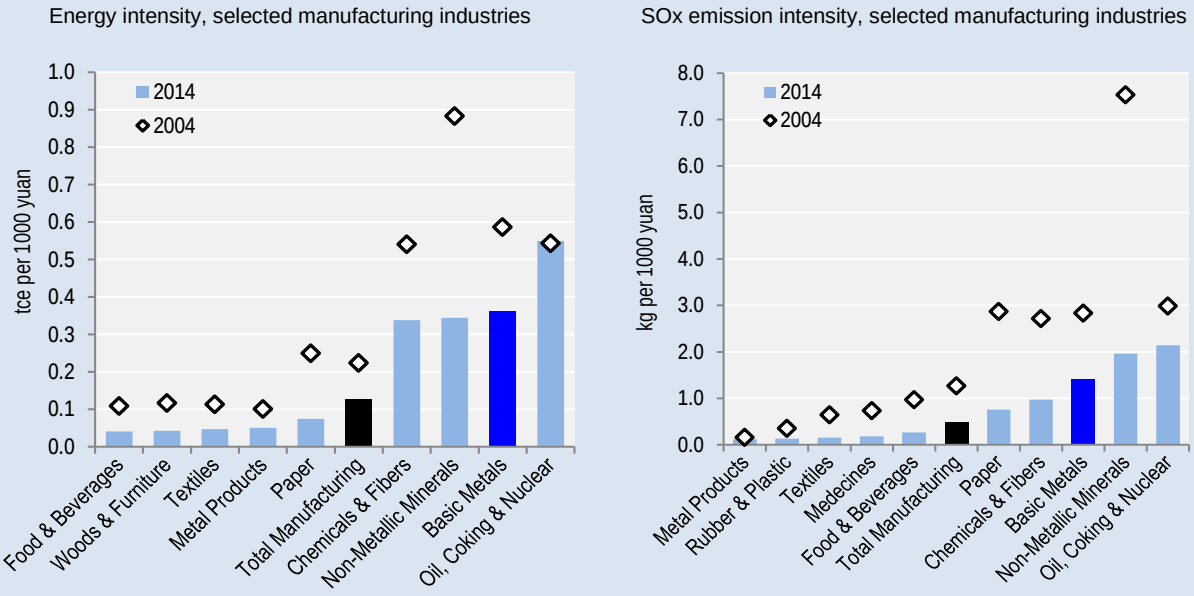
B. Trends in SO_2 emissions by sector, 2000-2014



Note: *Industry refers to the mining and quarrying, manufacturing and energy sectors.

Source: varied issues of Report on the State of the Environment in China, Environmental Data Handbook, and China Statistical Yearbook on Environment; IEA for CO_2 emission data.

Figure 16. Energy intensities have decreased in many manufacturing sectors, 2004-2014



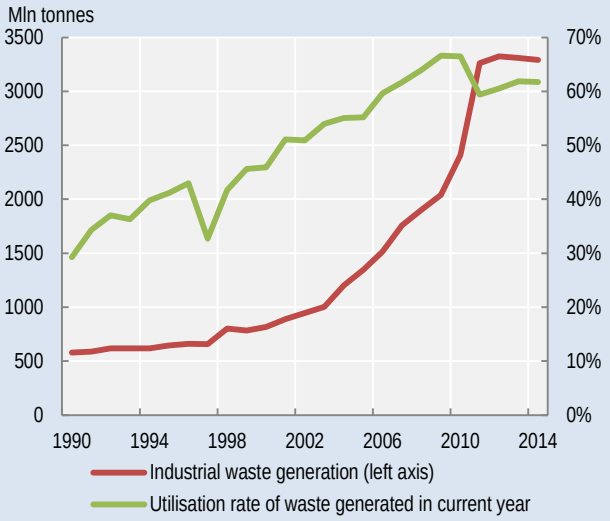
Source: China Environmental Statistical Yearbook, varied issues; sectoral value-added data are from the IHS World Industry Service and are calculated in real or inflation adjusted value terms.

While discharges of industrial wastewater remained stable since 1990, the amounts of waste generated by industry increased almost five-fold reaching 3.3 billion tonnes in 2014 (Figure 17). Given the significant expansion of industrial production over the same period, the waste generation intensity per unit of industrial value added, declined by almost 60% during the 1990s and remained stable throughout the 2000s. An increasing share of the waste is being recovered for recycling or re-use, in line with the implementation of China's Circular Economy policy (since the 12th Five Year Plan). More than 60% of the industrial waste generated in 2014 was "utilised", compared to about 45% in 2000 and 30% in 1990. Recovered materials and products grow on average by 0.3% annually. In 2015, China recovered a total of 246 million tonnes of scrapped metals, plastics, paper, glass, tyres, batteries, electrical and electronic equipment, automobiles and ships, representing a total value of 515 billion yuan.

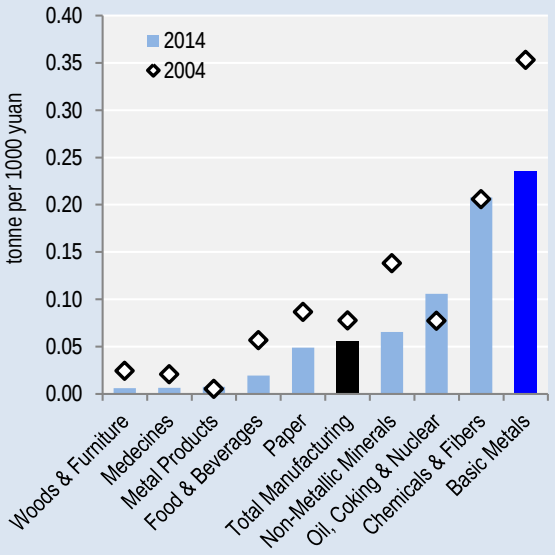
Many industrial air emissions have continued to increase but at a slower rate than industrial value added, displaying a relative decoupling. Some pollutants have started to decline in recent years, but emissions generally remain at levels that are too high. Most of the reduction of industrial SO_2 and NOx emissions since the peak years (respectively 2006 and 2011) was achieved in the energy production sector, while emissions from manufacturing industries grew (Figure 15.B). Given the high rates of GDP growth in China over the past 10-15 years, relative decoupling is insufficient to mitigate environmental pressures and reduce environmental damage. In 2014, industry still contributed more than 80% of total domestic SO_2 emissions and more than two-thirds of NOx emissions. As aforementioned, Hebei Province, which hosts a large steel industry, ranks highest for PM2.5 concentrations.

Figure 17. Waste generated by industry is growing, but is increasingly recovered

A. Trends in industrial waste generation, 1990-2014



B. Waste generation intensity, selected manufacturing industries



Notes:

1. The statistical methodology for calculating the indicators was revised in 2011; data before and after are not directly comparable.
2. Industrial waste refers to common and hazardous industrial solid wastes.
3. Industrial solid wastes utilised refers to the volume of solid wastes from which useful materials are extracted or which are converted into usable resources, energy or other materials by means of reclamation, processing, recycling and exchange. Examples of such utilizations include fertilizers, building materials and road materials. Only common industrial solid waste utilised and generated in current year is included in calculating the utilisation rate.

Source: *China Environmental Statistical Yearbook*, varied issues; sectoral value-added data are from the IHS World Industry Service and are calculated in real terms (2005 prices).

Many outdated production capacities have been eliminated in China since the implementation of the 11th Five-Year Plan (2006-2010), and the trends described above show that progress has been made in reducing some environmental pressures from industry. But there remains ample room for further progress and for converging with the environmental performance of the most advanced OECD countries, which have engaged substantial efforts to develop environmentally friendly technologies and production processes. Upgrading and restructuring the country's industry will be instrumental here.

2.5. Economic opportunities from green growth and the role of environmental policies and innovation

The characteristics described above create particular economic and environmental challenges for policy makers in China. Tackling these challenges requires strong environmental policies that are well aligned with economic and industrial policies, and effective environmental enforcement in all sectors of the economy.

2.5.1. Policy context and stringency

The Chinese government has already taken important steps to strengthen environmental policies and legislation. The first Environmental Protection Law was enacted in 1979, followed by a number of legislative acts covering specific areas of environmental

management, but the legislative and institutional framework remained weak throughout most of the 1980s and 1990s. The 11th, 12th and 13th Five Year Plans have progressively integrated more ambitious environmental policy objectives, and China actively uses policy instruments (e.g. taxes and subsidies) to promote the transition to green growth (Table 1).

Table 1. Environmental targets in China's 11th, 12th and 13th Five Year Plans (FYP)

Environmental issues and indicators		11th FYP (2006-2010)		12th FYP (2011-2015)		13th FYP (2016-2020)
		Target	Actual	Target	Actual	Target
Main air pollutant emission reduction (%)	SO_2	-10	-14.29	-8	-18	-15
	COD	-10	-12.45	-8	-12.9	-10
	NOx	-	-	-10	-18.6	-15
	Ammonia Nitrogen	-	-	-10	-13	-10
Energy supply intensity per unit of GDP (%)		-20	-19.1	-16	-18.2	-15
Carbon dioxide emission intensity per unit of GDP (%)		-	-	-17	-20	-18
Non fossil energy share in primary energy supply (%)		-	-	11.4	12	15
Water consumption per unit of industrial Added Value (%)		-30	-36.7	-30	-35	-20
Water consumption per unit of GDP (%)		-	-	-	-	-23
Total use of water (billion cubic meters)		-	-	-	-	< 670
Air quality	Days with good urban air quality[1] in cities at or above Prefecture-level	-	-	-	-	> 80
	Reduction of PM2.5 concentration in substandard[2] cities at or above Prefecture-level (%)	-	-	-	-	-18
Surface water quality	Surface water of at least Grade III quality[3] (% of monitored sections)	-	-	-	-	> 70
	Surface water worse than Grade IV quality (% of monitored sections)	-	-	-	-	< 5

Notes:

1. Good air quality refers to the Grade I and II in Air Quality Index (AQI), corresponding respectively to 0-50, and 50-100. 338 cities at the prefecture level and above are included in the evaluation.

2. Substandard cities refer to those whose PM2.5 annual concentration is higher than 35μg/m3.

3. As in other countries, China uses a grading system for monitoring and reporting surface water quality across the country, with Grade I water the highest quality and Grade V-plus the worst. The number of monitored water sections increases from 972 during the 12th Five-Year Plan period (FYP) to 1940 during the 13th FYP period.

According to OECD analysis, China's environmental policy has become more stringent in recent years; that is, environmental policy measures have increased the explicit or implicit cost of environmentally harmful behaviour. Building on the OECD's Environmental Policy Stringency (EPS) indicator, the analysis shows that since 2000, China's environmental policies concerning air and climate related issues have converged much more rapidly than other emerging economies[12] with those of OECD countries, particularly after 2010. It should be noted, however, that this indicator only weighs the stringency of selected environmental measures as defined in policy documents and laws and does not measure the effectiveness of their implementation.

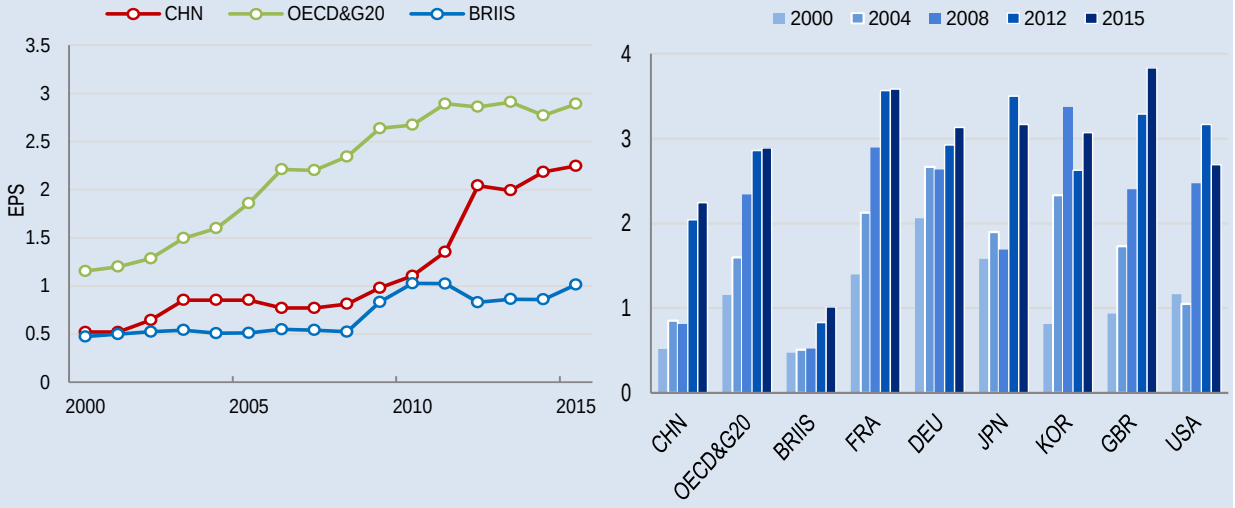
Environmental indicators are increasingly used to support decision making and monitor progress towards the Five-Year Plan targets, including through the regular performance evaluation of local leaders. Efforts are also underway to consolidate China's environmental monitoring systems and improve the information base and data quality for integrated environmental-economic policies. The changes recently introduced in the country's supervisory and monitoring system are expected to make pollution control more effective

12 Brazil, Russia, India, Indonesia and South Africa

and make it easier to assure the quality of data reported by provinces and local authorities to the central government (Box 1, p. 13).

Figure 18. Environmental policies have become more stringent

Environmental policy stringency index, 2000-2015



Note: Composite index focusing on policy instruments related to climate and air pollution from energy and transport, and covering instruments such as taxes, feed-in tariffs, renewable energy certificates, R&D subsidies and emission limit values.

Source: OECD (2017), "Environmental Policy Stringency index", *OECD Environment Statistics* (database).http://dx.doi.org/10.1787/2bc0bb80-en; drawing on data from oe.cd/pine.

2.5.2. Economic instruments and environmental taxation

China's environmental policies have been characterised by a broad use of command-and-control measures as well as subsidies; this is changing but these instruments were important for achieving the environmental targets in previous Five Year Plans. Substantial public financial support was for example provided to install end-of-pipe technologies to reduce emissions of SOx, NOx and COD, notably in the 11th Five Year Plan (CCICED, 2007)[13]. While this can be an effective way to achieve emission reduction targets in traditional sectors, it is not in line with the Polluter-Pays Principle, and removes incentives for enterprises to develop efficient means of reducing pollution, including by plant modernisation, and the use of integrated abatement technologies and of clean technologies.

In the past 10 to 15 years, the use of environmentally related taxes has been growing and the share of their revenues in total tax revenue and in GDP has increased significantly, in particular since the implementation of the 11th Five Year Plan. The revenue generated grew from 0.4% in 2000 to 1.3% of GDP in 2014, close to the OECD average. As in OECD countries, the tax base is dominated by transport and energy. Revenues from direct taxes on energy are lower than the OECD average (Figure 19). Efforts have also been made recently to phase out inefficient fossil fuel subsidies and to move towards more market-

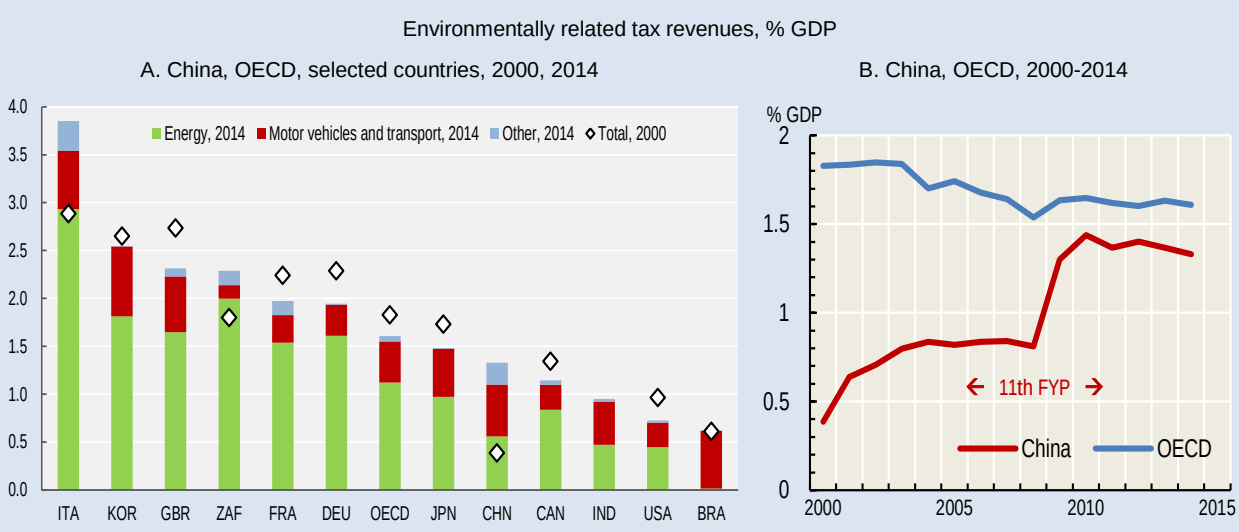
13 Examples include favourable prices for electricity generated by coal-fired power plants with installed desulphurization equipment (as of July 2007) and with installed denitrification equipment (as of January 2013).

based pricing of energy and resources. In many provinces, a resource tax applies to the extraction of natural resources (metal ores, fossil energy, industrial minerals) and to the non-agricultural use of farmland in several provinces, including Hebei. The Environmental Protection Tax Law passed in December 2016 is intended to help broaden the use of environmental taxation; its aim is to replace the existing pollution discharge fee system with a new environmental tax, address the issue of ineffective enforcement by levying pollution charges and encourage companies to reduce emissions.

More recently, China has played a leadership role in the G20 context to promote green finance (G20 Green Finance Study Group, 2016), and the People's Bank of China, together with several other institutions, has issued guidelines for establishing a green financial system (People's Bank of China, 2016). Amongst other things, this involves identifying ways to improve access to finance in order to comply with environmental requirements.

Figure 19. Environmentally related taxation is increasingly used

Environmentally related tax revenues, % GDP



Source: OECD Environment Statistics database.

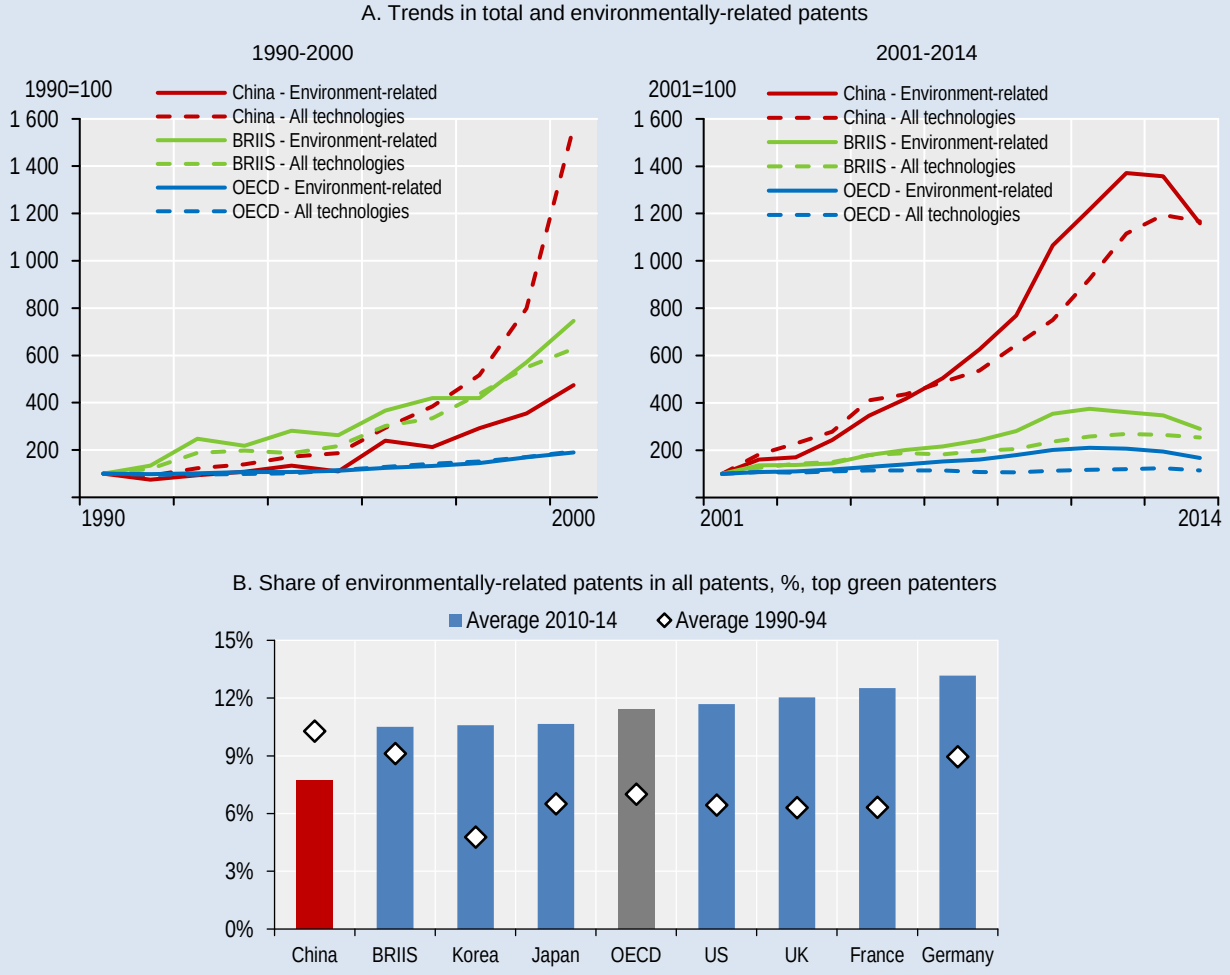
2.5.3. Innovation and technology development

China has also been active in fast-tracking environmentally related technologies. It has become the fifth largest country in filing environmental patents, making up 4.1% of the world stock during 2010-14, up from a mere 0.2% two decades ago. From 1990 to 2014, the number of environmental inventions has increased more than 60-fold in China, compared to a barely three-fold increase in the OECD area and 18-fold increase in BRIIS countries (Figure 20). It is also important to note that patenting in "green" technologies in China has surged in particular during the last decade, outpacing that of all technologies since 2005. Nonetheless, this speed appears to have slowed in 2013 and 2014, and the share of "green" patents in all patents remains lower than OECD countries. Questions also remain as regards the quality of the patents.

When looking at the technology domain, every one in five environmental inventions in China during 2010-14 occurred in environmental management, notably air and water pollution abatement; a small fraction concerned water-related adaptation, such as water conservation; while the vast majority (76%) were related to climate change mitigation,

particularly in building (e.g. more energy efficient lighting and information and communication technologies) and energy (e.g. renewable energy generation and the development of enabling technologies like battery storage, fuel cells and smart grids). Looking ahead, more information can be collected to assess the opportunities that innovation and technology development provide for greening the economy and creating new markets. For example, there is so far sparse information on the size of the environmental goods and services sector and its contribution to economic growth, and on recycling markets.

Figure 20. Environmentally-related technologies are developing rapidly



Source: OECD (2017d), "Patents in environment-related technologies: Technology development by inventor country", *OECD Environment Statistics* (database). http://dx.doi.org/10.1787/data-00760-en

3. China's prospects for aligning environmental and growth objectives in the context of industrial upgrading

The developments described above (section 1.2) indicate that China has a good potential for improving its environmental performance and achieving a greener growth. There are many untapped opportunities for efficiency gains, which are vital to the shift to a low carbon, resource efficient and competitive economy. They also indicate that the policies in place, though showing first results, remain insufficient to cope with increasing pressures and with historical and cumulated pollution loads. Part of the progress achieved was driven by government support measures and end-of pipe solutions. This raises questions as to future developments. Further progress will largely depend on the country's capacity to (i) integrate environmental aspects into decision-making in all policies and sectors, and at all levels, and (ii) ensure that economic and environmental policy objectives and measures are well aligned and support each other. This will require concerted action by all ministries (Economy, Industry, Commerce, etc.) whose policies affect the environment and which can promote green growth.

Against this background, industrial and environmental policies have a determinant role to play. And in the longer term, real productivity gains (in terms of EAMFP) will be instrumental to achieve the dual objectives of sustained economic growth and improved environmental outcomes.

3.1. Synergies between industrial and environmental policies

Industrial and environmental policies are inherently intertwined. China has come to a stage of development where well coordinating and aligning industrial and environmental policies and their implementation is crucial for the future development of the country. With a rapidly expanding economy, fuelled by industrial production and trade, *industrial upgrading* is an important means to mitigate negative environmental outcomes and their costs, and to create opportunities for a more sustainable economic development and a competitive industry. *Effective environmental policies* and measures to encourage green growth through innovation and well targeted investments are in turn important means to upgrade China's industries and to re-balance the industrial structure.

The emphasis on an ecological civilisation that pursues both economic and environmental objectives and on innovation in the 13th Five-Year Plan signal China's political will to move away from a "quantitative" growth path to a more balanced, higher-quality and greener growth path. This follows on earlier efforts to control pollution and to establish a circular economy. The achievement of these objectives will require an efficient combination of policy measures and adequate governance and coordination both horizontally across ministries and agencies, and vertically between levels of government. Adequate support to workers and communities affected by plant closures will also be needed to address transitional social impacts. This could be supported with a regular review of policy objectives and measures to identify possible misalignments at an early stage and to ensure that synergies can be used.

3.2. Effective industrial upgrading and restructuring

The 13th FYP foresees sustained economic growth and a progressive change in the economic structure, with a relative contraction of the share of industry and manufacturing in GDP and continued expansion of the service sector by 2020[14] (Box 2).

Box 2. Aligning medium-term economic growth and environmental objectives in China – A research study

China's 13th Five-Year Plan (FYP) aims at maintaining sustained economic growth with an average annual growth rate of 6.5% over 2016-20, while achieving domestic environmental objectives and international commitments under the Paris Climate Agreement. The Plan also foresees changes in the economic structure, with a further expansion of the service sector's share in the economy to 56% by 2020. The directions set to achieve this upgrading include the implementation of the *Made in China 2025* roadmap to consolidate the manufacturing base, expand emerging and frontier sectors to reach 15% of GDP by 2020, and foster greater specialisation and competitiveness in producer services.

A recent research study[15] quantified the extent of the structural changes within China's industry that would be required to meet the country's medium-term growth and environmental objectives. It considered the policy constraints related to the environmental targets set in the 13th FYP, while achieving the overall growth objective of 6.5% per year. Using environmentally extended input-output tables with a linear technology assumption, the study identified an "optimal" industrial structure that would satisfy those constraints and objectives simultaneously. It also estimated the "projected" industrial structure in 2020 under a business as usual scenario, using 2012 as the base year. The gap between the optimal and the projected structure was used to identify the required sectoral shifts.

The preliminary study results confirm that the 13th FYP targets are achievable, but meeting them simultaneously will require an extensive industrial restructuring and upgrading, involving both the traditional, heavy industry sectors and the more technologically advanced sectors.

- In the scenario where the technology level is predicted according to historical trends[16], the optimal GDP shares of a large range of manufacturing industries in 2020 would be significantly lower than their respective projected levels. The industries experiencing the biggest shrink in terms of GDP share include **basic metals** (including iron and steel, aluminium), **processing industries** (petroleum, coke and nuclear fuel) and **thermal power** that are energy-intensive and highly polluting. They account for more than half of total CO_2 emissions but contribute to barely 16% of the total economy (2012 data). Reducing the share of these industries in GDP does not necessarily imply an absolute output contraction from the 2012 level, only that the optimal growth rates over the 2012-2020 period in these industries need to be lower than their respective projected growth rates.
- In the scenario of more ambitious changes in the energy mix induced by policy objectives, increasing the share of non-fossil fuel resources in primary energy supply does not alter the direction of sectoral shifts but slightly reduces the extent of the adjustments. Promoting sectoral adjustments coupled with a greener energy supply structure would thus reduce CO_2 emissions further without hurting economic performance.

Some of the study's limitations should be borne in mind when interpreting the results. For instance, the estimates of future demand, human capital and physical capital constraints require more robust analysis. Nevertheless, the overall conclusions point to the importance of aligning industry, energy and environmental policies in the transition to a more efficient, cleaner and low carbon economy. In a business-as-usual scenario, short-term measures such as expanding infrastructure investment could result in stronger output growth in the energy-intensive sectors while further delaying progress in structural upgrading of the economy. Any stimulus package should thus be administered carefully, clearly time-bound, and accompanied by strengthened enforcement of stricter environmental requirements, and accelerated deployment of non-fossil fuel resources for industrial production.

[14] China's 13th Five-Year Plan (2016-2020) aims at maintaining a sustained economic growth with an annual average growth rate of 6.5%.

[15] Study carried out by Dr Fu Xue, Nanchang University, China.

[16] The energy-related carbon intensity per industry is predicted according to time series, which reflects changes in the technology of production (adjusted according to time series and RAS methods) and fuel substitution.

Restructuring and modernising China's industry will require incentives to encourage the exit of unprofitable, inefficient and polluting firms, but also a reallocation of financial resources to more productive and environmental friendly uses, and stronger incentives to support companies that satisfy high financial and environmental standards. The government has already taken steps to restructure and modernise heavy industry, to address overcapacity in some sectors, sustain industry's competitiveness, and improve environmental conditions. It also started to deploy measures to encourage the Next Production Revolution (NPR), with particular attention to new technologies such as digitalisation, new materials and industrial processes. Initiatives such as the "Made in China 2025" and "Internet Plus" aim to establish China as a global manufacturing power within the next decade, while at the same time lowering energy and material consumption and pollutant emissions per unit of industrial value added[17, 18].

While new and cleaner technologies can reduce material consumption and provide alternative materials that are less hazardous than those in use, they may also entail new environmental risks. These risks need to be assessed and managed to avoid that regulatory uncertainty and public opposition prevent their uptake (e.g. by developing sustainability standards for the bio-economy, and establishing a regulatory framework for managing waste streams involving nanomaterials).

3.3. Effective environmental policies for industry

In recent years, China has significantly strengthened its environmental policies and legislation. While effective in the Chinese context, policies have been narrowly focused and were not always efficient enough to address the complex set of environmental challenges that China faces. Experience from OECD countries indicates that ultimately a broader mix of policy instruments – with greater use of market-based instruments – will be needed, associated with an effective monitoring of environmental compliance in all sectors and an integration of environmental aspects as of the early planning phases of projects and policies.

Environmental policies for the industrial sector could thus become more effective if they were supported with systematic environmental impact assessments (EIA), an integrated permitting system, and greater disclosure of environmental information to the public. Environmental enforcement will also need to be strengthened and made more consistent across the country in order to establish an environmental level playing field for all companies.

3.4. Effective environmental governance and policy coordination

The 13th Five Year Plan acknowledges that the transition to an ecological civilisation and green growth requires environmental governance to be strengthened. This includes strengthened coordination between central authorities and Provinces, and between the

17 One of nine strategic tasks of the "Made in China 2015" initiative is "green manufacture", and one of five strategic projects is "energy efficiency improvement, clean production, water conservation and pollution control, and recycling in traditional manufacturing industries".

18 The "Internet Plus" initiative includes an environmental component focussing on improved environmental monitoring and support for waste recycling through the development of a system for trading in waste.

Ministry of Ecology and Environment (formerly known as the Ministry of Environmental Protection, hereinafter MEE) and other Ministries whose policies affect the environment. Effective coordination between the MEE, NDRC and MIIT, MOA, MWR and MNR[19], amongst others, is vital to align environmental and industrial policies. The implementation of the FYP also provides an opportunity to review the role, structure and operation of the MEE and of other Ministries and agencies with environmental responsibilities.

3.5. Effective environmental information systems

Aligning China's economic and environmental objectives will also require further efforts to consolidate the country's ***environmental information*** system throughout the information chain, from monitoring and statistics to indicators, reporting and policy evaluation.

One challenge that China shares with many other countries, is that environmental data are produced by many different ministries and agencies at many government levels, and hence not easy to integrate, harmonise and share. Recent efforts to improve the reliability, accuracy and comparability of environmental data through better institutional settings aim at addressing this challenge. Particular attention is given to data from environmental monitoring systems, and to the re-organisation of the data flows in a way that enables a centralised quality control of the date submitted by sub-national authorities (see also Box 1, p. 13).

Another challenge, also shared with other countries, is the lack of economic information on the environment and of information on "green" industries and technologies, such as those of the environmental goods and services sector. Better and more comprehensive statistics could be developed to measure "green" production, finance and investment, environment-related R&D, environmental expenditure, including investments, and environmentally related transfers. Fostering the implementation of environmental-economic accounts, would further facilitate a more systematic monitoring of the environment-economy integration. Improved and harmonised physical and monetary information on the consumption of raw materials and natural resources in the economy and in industrial processes would be useful to monitor resource productivity and identify opportunities for efficiency gains in industry and in value chains.

China's set of ecological civilisation indicators is a promising tool to monitor progress towards green growth and the objectives of the 13th FYP, and to enhance public information and the accountability of sub-national governments. The use of these indicators and the composite green development index in the performance evaluation of senior subnational government officials (Box 1), is a pioneering initiative that provides a basis for strengthening the oversight of subnational progress by the central government. More generally, experience in OECD countries shows that producing high quality information on the environment and on the economic opportunities generated by integrating environmental aspects into decision-making, also helps engage the public and NGOs in the development and implementation of environmental policies. A regular exchange of experience between China and OECD countries on good practices and lessons learned from the use of indicators and information in policy-making would thus be of mutual benefit.

[19] The abbreviations respectively stand for: Ministry of Ecology and Environment, National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Agriculture, Ministry of Water Resources and Ministry of Natural Resources (formerly known as Ministry of Land Resources).

References

Cárdenas Rodríguez M., Haščič I. and Souchier M. (2016), "Environmentally Adjusted Multifactor Productivity: Methodology and Empirical Results for OECD and G20 Countries", *OECD Green Growth Papers*, No. 2016/04, OECD Publishing, Paris, https://doi.org/10.1787/5jlr2z7ntkf8-en.

IEA (2016), *World Energy Outlook 2016*, International Energy Agency, Paris, https://doi.org/10.1787/weo-2016-en.

OECD Environment Statistics (database) https://doi.org/10.1787/env-data-en

OECD "Green Growth Indicators", *OECD Environment Statistics* (database) https://doi.org/10.1787/data-00665-en

OECD (2017a) *Nowcast TiVA Estimates: Methodology*, Paris, http://www.oecd.org/sdd/its/tiva-nowcast-methodology.pdf

OECD (2017b), *OECD Economic Survey of China*, OECD Publishing, Paris, https://doi.org/10.1787/eco_surveys-chn-2017-en.

OECD (2017c), *The Next Production Revolution: Implications for Governments and Business*, Paris, https://doi.org/10.1787/9789264271036-en.

OECD (2017d), *OECD Green Growth Indicators*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264268586-en

OECD (2017e), *Investing in Climate, Investing in Growth*, OECD Publishing, Paris, https://doi.org/10.1787/9789264273528-en.

OECD (2016), *G20 Innovation Report 2016*, prepared for the G20 Science, Technology and Innovation Ministers Meeting, November 2016, https://www.oecd.org/china/G20-innovation-report-2016.pdf.

OECD (2015a), *OECD Science, Technology and Industry Scoreboard 2015: Innovation for Growth and Society*, OECD Publishing, Paris, https://doi.org/10.1787/sti_scoreboard-2015-en.

OECD (2015b), *OECD-WTO Trade in Value Added*, country note on China, available at: http://www.oecd.org/sti/ind/tiva/CN_2015_China.pdf

OECD (2015c), *Towards Green Growth? Tracking progress*, OECD, Paris. http://www.oecd.org/environment/towards-green-growth-9789264234437-en.htm

OECD (2015c), *Aligning Policies for a Low-carbon Economy*, http://www.oecd.org/environment/Aligning-Policies-for-a-Low-carbon-Economy.pdf

OECD (2013), *OECD Economic Survey of China*, OECD Publishing, Paris, https://doi.org/10.1787/eco_surveys-chn-2013-en

OECD (2002), *China in the World Economy: The Domestic Policy Challenges*, OECD Publishing, Paris, https://doi.org/10.1787/9789264196278-en.

UNEP (2016), *Global Trends in Renewable Energy Investment 2016*, http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf.

UN Environment, *International Resource Panel, Global Material Flow* (database) http://www.resourcepanel.org/global-material-flows-database

www.oecd.org/greengrowth