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CHINA 2.0

STATUS AND FORESIGHT OF EU-CHINA TRADE, INVESTMENT AND TECHNOLOGICAL RACE

Joint Research Centre

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EXECUTIVE SUMMARY

EU-China relations: between cooperation and competition

China's present role in the global order challenges the EU's ambition for open strategic autonomy, calling for a careful reassessment of the EU's trade, technological and industrial policies, and its overall global ambitions. Finding the right balance between cooperation and competition with China requires the EU to acknowledge the balance that must be struck between its commitment to openness and free trade on the one hand, and coping with restrictive policies imposed by China on the other.

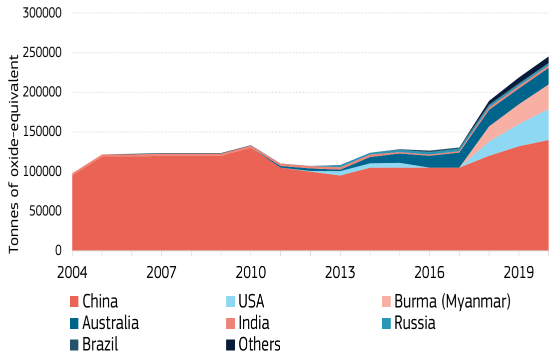
The overall policy framework to manage the complexity of opportunities and challenges posed by China is set out in the 2019 Strategic Outlook of the EU-China relations. China is considered "simultaneously, in different policy areas, a cooperation partner with whom the EU has closely aligned objectives, a negotiating partner with whom the EU needs to find a balance of interests, an economic competitor in the pursuit of technological leadership, and a systemic rival promoting alternative models of governance."

The EU may need to cope with a greater dependence on China in the short term, due to higher demand for materials and products for critical industries, including those for the green and digital transition. A large share of EU imports (e.g. consumer electronics and apparel) strongly depend on China. Among them, final goods such as cameras, multifunction printers, flash memory cards and most garments show high import dependence (80% or more of the total supply), a high share of imports from China (40% or above), and China's high global market share for these products (with a share in the 40-50% range). The strong dependence on products to tackle COVID-19 at the outbreak of the pandemic (such as LED lamps and facemasks), for which China had a dominant position on the world market, was illustrative of the risks and vulnerabilities to be addressed.

Dependencies concern raw materials and critical resources for EU value chains. 30% of raw materials production and 40%-50% of processed materials worldwide are concentrated in China.

Strategic sectors deserve particular attention, as in many of them China is also a major supplier of raw materials and of products along the whole supply chain. At the global level, China supplies an average of 30% to 40% of raw materials, processed materials, components, and final assemblies in nine technologies. These are batteries, fuel cells, wind power, electric traction motors, solar photovoltaics (PV), robotics, drones, 3D printing and ICT. The EU only supplies about 20% of processed materials and assemblies, 10% of components, and 3% of raw materials. China's share of manufacturing reaches even higher, quasi-monopolistic levels in fields such as batteries (66%), solar PV modules (70%), solar PV cells and wafers (89%), and rare earth permanent magnets (90%).

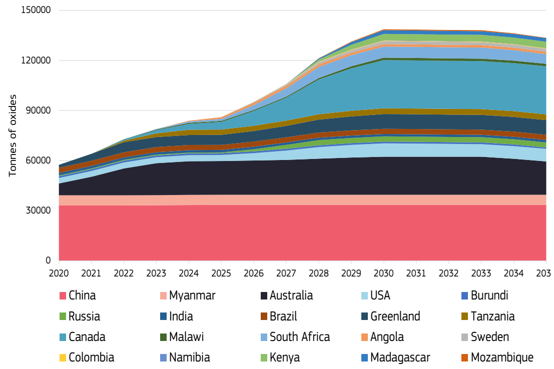
Figure 1: Production of rare earth elements over 2004-2019



Note: Chinese official production only.
Source: USGS (2005-2020)

This also highlights China's consolidation in higher-value segments downstream in the supply chain, which is particularly clear in the case of rare earths, where China has used its dominance in mining and refining to stimulate the manufacturing of alloys and magnets.

Figure 2: Future distribution of rare earth supply



Note: oxides used in permanent magnets only.
Source: JRC (Alves Dias et al., 2020)

Recent developments in EU-China trade, investment, and technological competition

Chinese Mergers and Acquisitions (M&A) grew by 21% between 2017 and 2020 compared to 2013-2016. This is the highest rate for inbound deals from any strategic partner. Manufacturing, and high-tech companies in particular, attracted the largest share of Chinese M&A deals in the EU (more than 47%) between 2013 and 2020, in different segments of the value chain.

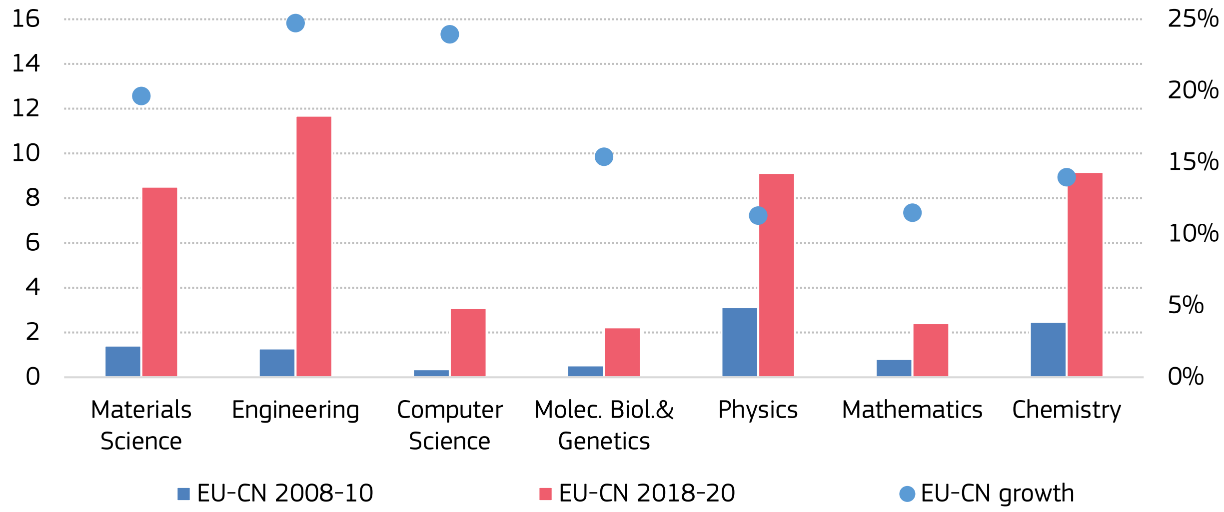
Chinese M&As in the EU fell during the COVID-19 pandemic, due to the reorganisation of global value chains (GVCs), together with the new development strategies pursued by the Chinese government called Made in China 2025 (MIC2025). Between January and December 2020, total Chinese foreign direct investment (FDI) deals in the EU were 36% lower than in the same period of 2019. The negative shock due to the pandemic was stronger for greenfield investments than for M&As. Chinese FDI activity in the EU continued to fall in the first quarter of 2021, and investments by China's state-owned enterprises (SOEs) consistently followed this trend. As of 2019, the reduction in the number of M&A deals in high-tech and low-tech sectors coincides with a slowdown in trade flows between the EU and China. Support to boost domestic demand and improve China's supply chain through FDI or technological upgrading denote China's **dual circulation strategy**. This entails improving China's domestic conditions and increasing exports by diversifying the sources of imports away from developed economies, particularly the US, and redirecting exports towards emerging economies as per the *Belt and Road Initiative* (BRI), to promote open emerging markets.

The EU-China trade deficit is driven by higher import dependence on China and market restrictiveness *vis-à-vis* the EU. EU companies' access to the Chinese market is hampered by a lack of transparent regulation and intellectual property (IP) protection, and preferential treatment for domestic producers. For example, access to the Chinese market remains challenging in the wind energy sector, relying on partnerships and licensing agreements with Chinese counterparts. Although Chinese IP protection improved in the last decade, a number of infringements explain why in 2020 EU companies refrain from bringing innovative technologies to China.

Electronic and ICT companies in the EU are attractive for Chinese investors in a period of economic turmoil, especially for semiconductors. FDIs by Chinese SOEs and private entities in EU companies operating in the electronics and ICT sectors reached a peak in 2017, due to acquisitions made by Chinese SOEs. Interestingly, the total value of deals in 2020 was three times larger than in 2019, thus confirming the interest from Chinese investors. The complexity of the ownership structures in private Chinese companies and the heavy reliance on state financing often dilutes the distinction between private and state-owned companies.

A significant upgrading of the ICT manufacturing sector is taking place in China, with a clear shift away from low-tech sectors. Semiconductors, optics and audio-visual technology are the fields that have seen the largest increase both in terms of total number of patents and specialisation. This is in line with China's growth in terms of the top research and development (R&D) investing companies (China: + 61 while EU: -20 in 2019-

Figure 3: International co-publications relevant for the Chinese Revealed Scientific Advantage (RSA)



Note: n = thousands of research papers, Compound Annual Growth Rate (dots).
Source: JRC elaboration based on INCITES (Web of Science) data

2020) and respective R&D share (CN: +9.6% in 2014-2020). This growth is mainly at the expense of the EU and Japan, whose share has declined in recent years (EU: -3.6%, JP: -2.1% in 2014-2020).

In response, the EU should boost its research and innovation (R&I) performance, also in light of the continued increase in China's high-impact publications. China has overtaken the EU in terms of its share of the top 1% most cited publications in the world. By 2020 it had almost caught up with the US, whose share of the top 1% most cited publications (about 1.6% in 2019) has been decreasing for the last five years. China's specialisation is most impressive in the fields of molecular biology and genetics, with a very significant growth in publications, and a level of specialisation almost equal to the US, the most specialised in these fields overall. In the fields relevant to its scientific specialisation, China co-publishes more with the US than it does with the EU. Growth is also consistently higher in US-CN co-publications than for EU-CN ones, particularly in the field of materials science. While the Chinese market traditionally attracts foreign businesses because of its size and growth potential, its inherent challenges led to widespread negative sentiments among EU businesses and investors at the onset of the pandemic. EU exports to China are dominated by western European countries with Germany ranking first, and much higher than the rest. Moreover, **protection of IP will remain key** in securing the EU's technological leadership in the future.

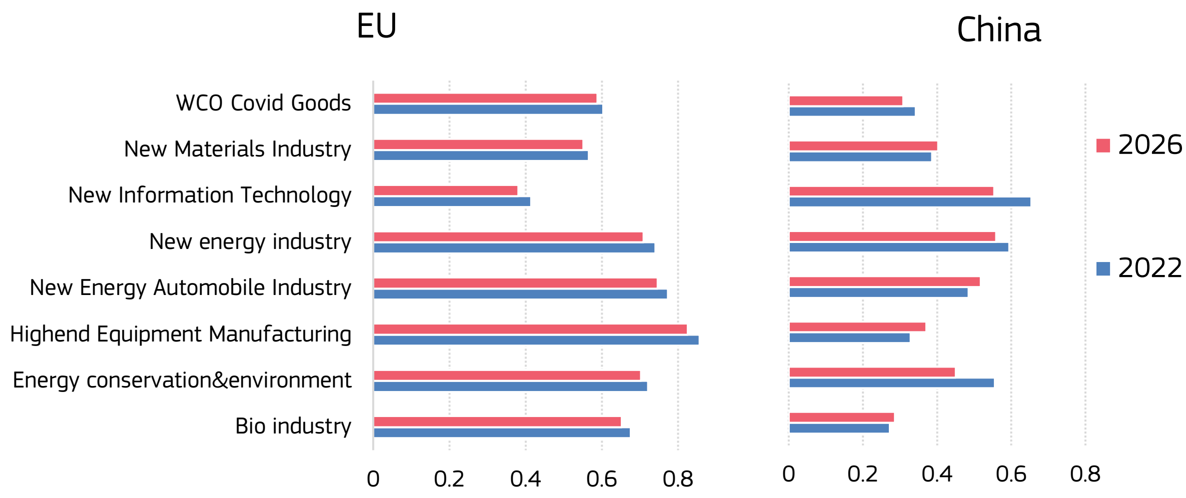
Long-term trends affecting the EU's and China's competitiveness in strategic sectors

By 2050, rising demand in the EU for critical raw materials in a number of strategic sectors relevant to the twin green and digital transition (batteries, fuel cells, wind power, electric traction motors, solar PV, robotics, drones, 3D printing, and ICT) may be up to 58 times greater than the current consumption in all applications for lithium, 15 times greater for cobalt, 14 times greater for graphite, and 12 times greater for dysprosium.

Since 2015, the largest share of the global wind energy capacity is deployed in China, while in 2019 EU companies accounted for only 2.5% of the new capacity installed. China is also expected to prevail in the mid- to long term in wind energy generation, with 800GW of cumulative wind capacity in 2030 and 3000GW in 2060.

China's competitiveness has steadily grown in industries of future strategic relevance for the EU, while the EU is competitive in areas linked to the green transition. In recent years China improved the complexity of its production structure in most

Figure 4: Product progression probabilities in selected fields



Note: Product progression probability represents the probability that a country will become (or remain) a globally competitive exporter of a given product within a five years horizon.
Source: JRC computations based on COMTRADE data

high-tech sectors such as ICT, materials and energy. The EU is competitive in sectors related to the twin transition but forecasted to lose relative trade competitiveness in the long run, while China has positive prospects in four sectors: new materials, new energy automotive, high-end equipment and bio-industry.

Looking into the most relevant products under each of the priority sectors in which China is likely to remain a competitive exporter, neither the EU nor China (and similarly the US) are able to be generally competitive in all of them. For products related to 'Industry 4.0', the EU is likely to remain in the lead in industrial robots, but with a low level of competitiveness expected for some components, such as processors (where the US is in the lead) and memories. China would still prevail in wind energy generation but for products related to the wind energy industry the EU should remain competitive overall. China (and even the US) would fall behind in high voltage distribution panels and meteorological surveying equipment.

On the other hand, the EU has generally worse prospects than China or the US in new functional materials. Interestingly, the US would lead in polarising materials but not in technologically related optical fibres, which points in favour of **possible complementarities between different economies**. In new energy automotive products, the EU would still lack competitiveness in lithium-ion cells vis-á-vis China, while the US does not show good prospects in low-power AC electric motors, used in hybrid vehicles. Finally, the EU could perform better than China and US in rail transportation equipment, while the US has good prospects in traffic control equipment and locomotives, but not in railway maintenance vehicles.

These examples show the heterogeneity of product-level competitiveness in strategic sectors of high technological complexity and the interdependence between the most advanced economies. **This points to the important role that GVCs will continue to play and the need for the EU to preserve the open dimension of its strategic autonomy agenda and enjoy its benefits based on the complementarity of its partners.**

Policy implications

This report emphasises long-present and persistent trends and could not obviously address political developments of the recent months prior to its publication. Furthermore, EU-China relationships are also influenced by direct US-China developments, due to long-standing ties, commitments, and security arrangements.

Nevertheless, on the basis of the analysis carried out, a regular **evidence-based assessment of the future prospects in EU-China relations** appears crucial. Striking the right balance with China between competition and collaboration appears particularly challenging and important. Wide-ranging aspects related to fairness in trade conditions, access to markets and reciprocity in EU-China relations need to be taken into account. The analyses and results contained in this report point to the following policy implications:

- ***The EU may need to reduce its dependence on China in materials and products for critical industries*** *to reach its objective of competitive sustainability, for which open strategic autonomy in technology is needed. Some dependencies can be addressed through diversification or domestic production, while others might be conducive to vulnerabilities such as those arising from lack of alternative suppliers or high transaction costs. Resilience is therefore needed to mitigate supply chain disruptions* and *respond to sudden challenges such as those that emerged from the COVID-19 pandemic or the war in Ukraine, and to limit the impact of those that may occur in the future.*

- ***Current trade relations need to be re-examined to enable, in the long term, technology diffusion through trade.*** *Trade relations are unbalanced and indicate persisting Chinese market barriers created by a set of policies that protect China's domestic market (e.g. local content requirements, import tariffs and local VAT exemption).*

- *The nascent but* ***rising offshore wind market presents the opportunity for the entry of EU companies,*** *given their experience in crucial segments of the supply chain. In particular, cooperation in the offshore installer market might be crucial for the Chinese offshore wind market, as the availability of installation vessels does not match current deployment plans.*

- ***The EU's long-term targets for the twin transition and the pursuit of open strategic autonomy highlight the need for a secure supply of critical materials and products, particularly in cases where China's dominance in the market (e.g. rare earths, li-ion batteries) makes the value chains extremely vulnerable.*** *The current global chip shortage highlights the major impact that similar disruptions may have on industry. To tackle the EU's exposure to Chinese and other global suppliers, well-targeted interventions could lead to: (i) diversifying the materials supply; (ii) improving manufacturing opportunities in the EU; (iii) recycling, reusing and substituting materials and products; (iv) promoting corporate R&D and more effective implementation of science, technology and innovation policies and support instruments; (v) developing relevant skills and competences; (vi) enhanced collaboration with like-minded partners; and (vi) fostering international collaboration and standardisation activities.*

- ***The EU and China have an opportunity to align commonly applied criteria in key industrial sectors,*** *involving efforts to make cross-border supply chains more sustainable and to extend producer responsibility. Collaboration among EU, China and US on the global setting of standards may help preventing a tech divide and enforcing democratic accountability and transparency. Adopting standards for the design and development of new products, as well as tracking and monitoring of material flows, may help to create a policy dialogue to collaborate on roadmaps and targets to measure socio-economic and environmental impacts.*

TRADE AND RECIPROCITY – KEY FINDINGS

The EU-China trade deficit is driven by greater Chinese competitiveness, import penetration and dependence, and market restrictiveness vis-à-vis the EU

Trade penetration of imports from China to the EU[1] nearly doubled between 2000 and 2019, with China's imports being three times cheaper than EU exports. Manufacturing was the main sector driving this trend. China's accession to the World Trade Organization (WTO) has provided a stimulus to stronger trade integration between the two trading partners. The growth of Chinese exports to the EU has led to an increase in the EU's trade deficit with China from USD 49 billion in 2001 to almost USD 250 billion in 2008. Since then, it has stabilised at around USD 160 billion.

Products with the highest import dependence from China are also heavily imported by the EU, while China has a dominant position on the world market for them. Overall, the deepening of EU-China trade integration is driven mainly by the manufacturing sector. For the China dependant EU imports a strong positive association exist between the shares they represent in the total of EU imports and the share of China in world exports dimensions. This indicates a correspondence between China´s trade specialisation and the geographical origin of EU imports.

The COVID-19 crisis has revealed the vulnerability of the EU's supply chains to critical goods in the fight against the pandemic such as LED lamps and facemasks imported from China. China dominates the global market of LED lamps with a share of 70 % of total world exports, and it accounts for 37.3 % of all the EU imports of LED lamps. During the pandemic, those were used for disinfection purposes. In 2018, one in three facemasks imported by EU countries came from China. The EU needs to assess the vulnerability of its (essential) supply chains, and to take action to reduce them and ensure resilience.

China increased the complexity of its production structure and its competitiveness in key sectors, while the EU and US have shown a regressive pattern. China has improved the complexity of its production structure in most sectors, catching up with the US in ICT, materials and energy. Furthermore, China priority products that coincide with sectors in which the EU and US are particularly strong. At the same time, the EU has made improvements in new energy automobile and high-end equipment but has lost ground on new materials and ICT, while the US has seen a consistent decrease in all the sectors considered, with the exception of the new energy automobile sector.

China is likely to remain competitive in key sectors such as consumer electronics and protective goggles, while complementarity with the EU and US may be found in fields such as wind energy and new energy vehicles. The EU as a whole is the most diversified economy in the world in terms of competitively traded goods (2650 products). The EU also shows the highest level of economic fitness (2.89), far behind followed by China (2.29) and the US (1.93).

The regulatory framework in China has been improving, but future progress is uncertain. Despite positive regulatory changes, risks of IP infringement remain one of the main reasons behind the unwillingness of EU firms to bring their newest technological developments to China. 40% of respondents to the 2022 Business Confidence Survey reported IP infringement cases within last year (European Chamber of Commerce (ECC), 2022).

TRADE INTEGRATION AND MARKET ACCESSIBILITY

1.1 The EU-China trade deficit has grown over the last decade and stabilised in recent years

China is the EU's largest source of imports and its second largest export destination. China's accession to the WTO has provided further stimulus for EU-China trade[2]. Since 2001, exports of EU goods to China have been increasing by over 10% a year, while exports of services have increased by more than 15% a year (Alicia Garcia-Herrero, 2020). Simultaneously, the growth of Chinese exports to the EU has been even more pronounced, leading to an increase of the EU-China trade deficit from USD 49 billion in 2001 to USD 250 billion in 2008. Since then, this deficit has stabilised at USD 160 billion (Figure 1.1, 1st panel).

This trade imbalance is remarkably heterogeneous across sectors, with manufacturing being the main driver of the EU-China trade deficit, fluctuating around USD 200 billion USD from 2008 to2016 (Figure 1.1, 2nd panel). This deficit comes as a partial result of the international fragmentation of production of European companies and relocation of their manufacturing to China. A trade surplus in the services sector has instead been rising in recent years after a downward trend between 2008 and 2012 (Figure 1.1, 3rd panel).

This aspect points to the increased competitiveness of European services activities, particularly those related to financial services. Interestingly, the trade surplus in energy resources is also improving and catching up with the service sector surplus (Figure 1.1, 3rd panel).

1.2 Greater long run EU-China trade integration is driven by manufacturing

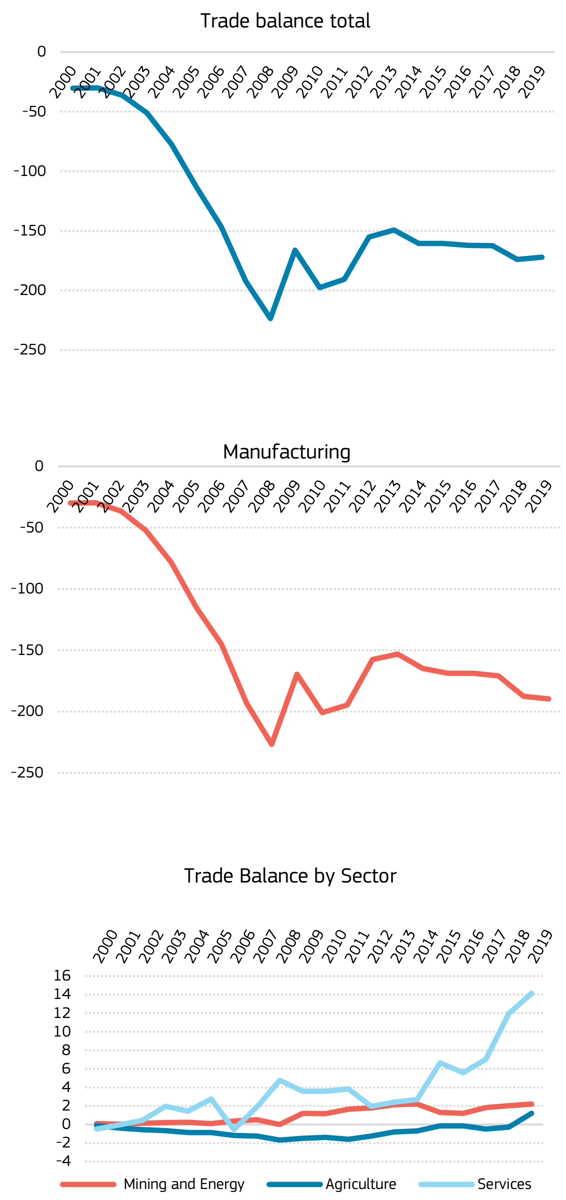
Larger bilateral trade flows between two countries, compared to their intra-national trade flows, imply deeper trade integration between them. Trade integration between China and the EU has been growing steeply since 2015 (Figure 1.2, 1st panel). This positive tendency is fundamentally driven by the manufacturing sector (Figure 1.2, 2nd panel), although integration in the service sector is also increasing (Figure 1.2, 3rd panel).

However, changes in the trade integration index might also come from changes in intra-national flows. In this sense, a fall in intra-national flows, as a result of lower domestic economic activity, could have an upward effect on the trade integration index, even when trade between two countries might have not increased accordingly. For example, the fall in European intra-national trade might have been the reason behind a sudden increase in the EU-China trade integration index in 2012.

1.3 EU-China market accessibility suffers a sharp decline in 2015

Figure 1.3 computes the market accessibility of the EU vis-à-vis China and that of China towards the EU. Both indicators[3] show similar trends, with a higher accessibility for the EU towards China than the other way around. On the discrepancy in trade accessibility between the EU and China, the latter appears to benefit more from its access to the EU single market. In 2002 this reached a peak thanks to the entry of China into the WTO regime. Since then, the accessibility of both markets has followed the EU's business cycle. This is shown by a fall in 2009 in the aftermath of the global financial crisis and due to the collapse in international trade. A sharp decline is visible in 2015, followed by some recovery in recent years.

Figure 1.1: Aggregate trade balance EU-China (1st panel). Sectoral trade balance EU-China: Manufacturing (2nd panel) and Services, Agriculture, Mining and Energy (3rd panel)

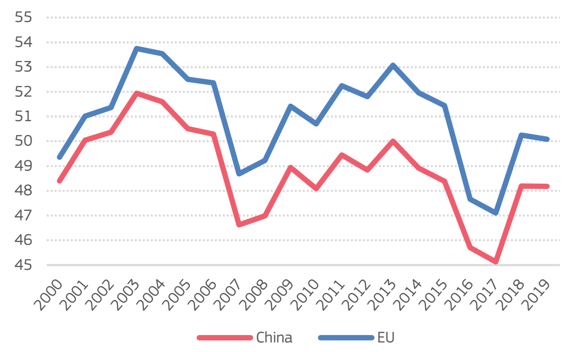


Source: JRC elaboration from International Trade and Production Database for Estimation (ITPD-E)

Figure 1.2: Trade Integration Index EU-China[4]. Aggregate trade flows (1st panel); Manufacturing (2nd panel); Services, Agriculture, Mining & Energy (3rd panel)

Source: JRC calculations from International Trade and Production Database for Estimation (ITPD-E)

Figure 1.3: Market accessibility EU and China



Note: Log-scale. Trade market accessibility measured through the market potential indicator[5], accounting for internal-external demand and trade frictions. The higher the market potential of a country, the more accessible the domestic market.

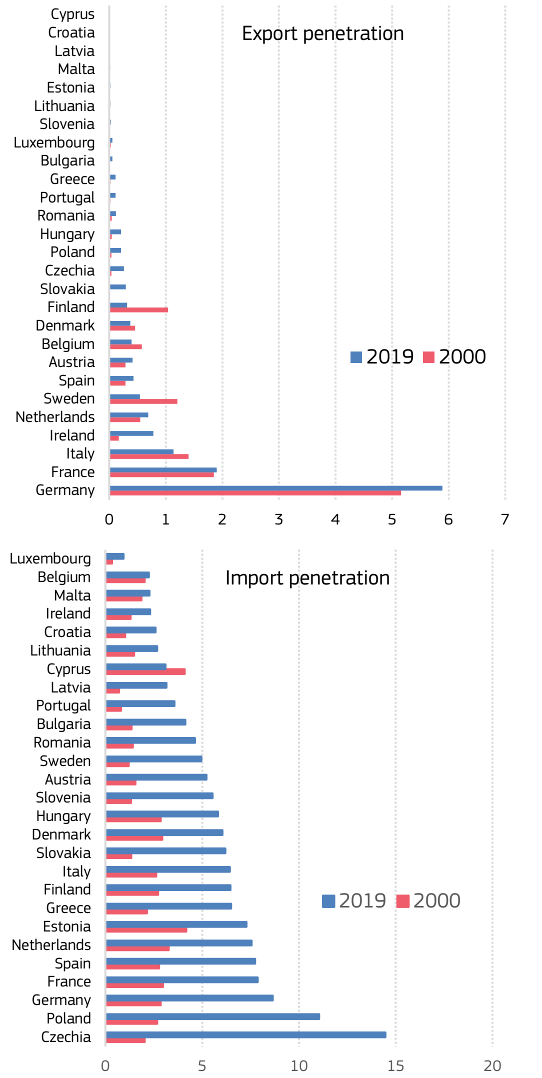
Source: JRC calculation from International Trade and Production Database for Estimation (ITPD-E)

1.4 EU exports to China are unevenly distributed while the penetration of Chinese imports to the EU is increasing

Export penetration into the Chinese market presents an uneven geographic distribution across EU countries (Figure 1.4, 1st panel). The biggest shares are among western European countries, whereas eastern Europe is lagging behind, with only sluggish improvement since 2000. Germany ranks first, and is the only Member State to have significantly increased its export penetration. Although the Netherlands and Spain also increased their exports in 2019, their export dynamics and penetration are far below Germany's. On the contrary, countries such as France, Italy, Finland and Sweden have significantly reduced their export penetrations into the Chinese market.

On the other hand, import penetration from China represents an increasing share of total imports in the EU (Figure 1.4, 2nd panel). Since 2000, most of the EU Member States have significantly increased their imports from China, with the largest importers being Germany, Poland, Czechia, Slovakia and Slovenia.

Figure 1.4: Trade penetration of EU exports (1st panel) and China imports (2nd panel). Share of EU exports (imports from China) over total exports (imports)



Note: Trade values are expressed in million USD.

Source: Own elaboration from International Trade and Production Database for Estimation (ITPD-E)

This tendency points to a deeper geographical specialisation of EU imports. This level of import penetration is the result of the increasing competitiveness of Chinese manufacturing products and the deepening of the EU-China trade integration process into GVCs, as highlighted in Figures 1.2 and 1.3.

1.5 Quality upgrading of EU-China trade flows in each technological classification

Figure 1.5 shows that, on average, the prices of Chinese imports are three times lower than the prices of EU exports[6]. Germany, France, Italy and Spain show the widest gap between prices. Although the gap shrunk since 2000, it is still among the main reasons for the increasing trade penetration of Chinese imports (Figure 1.4, 2nd panel). At the same time, the gradual decline in the export-import price ratio points to a progressive quality upgrading of Chinese exports to the EU. The most significant increase in Chinese exports to the EU between 2000 and 2019 can be seen in the high-tech products category (Figure 1.6, 1st panel). Meanwhile, exports of European products to China increased more evenly across all technological classifications (Figure 1.6, 2nd panel).

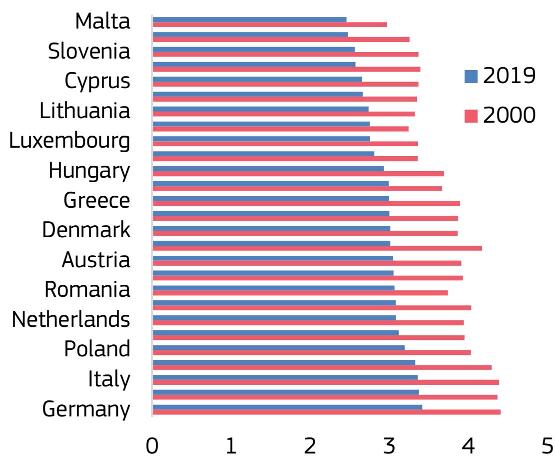
1.6 EU-China trade integration is below its potential to ensure a level playing field

Over recent decades, both the EU and China have made increasing efforts to intensify their trade relationship. Both economies are further integrating into GVCs, first, in the manufacturing sector and, more recently, in the service sector. As a result, the EU has developed a trade deficit with China in manufacturing; and a trade surplus in services. Despite sharp declines and differences between Member States, there has been a positive evolution overall in the EU's trade accessibility to China.

However, stronger efforts are needed for trade integration in services to ensure a level playing field. Although this sector improved its trade balance overtime, results indicate that trade integration is below potential. Further cooperation is needed to strengthen integration with China in service activities such as financial services, tourism and travel, telecommunications, transport and business services.

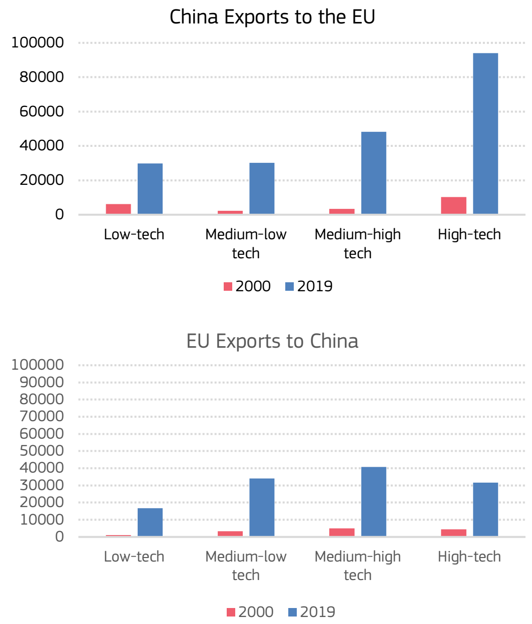
On the penetration of Chinese imports, the EU can benefit from geographically diversifying imports from countries other than China. This would help reduce the vulnerability of EU trade to unexpected shocks, such as the COVID-19 pandemic. The export-import price differential with China also needs to change to reduce the current trade deficit in the manufacturing sector. Reducing production costs mainly through lower nominal wages could lead to a loss of purchasing power for the EU. Instead, upgrading the quality of European products can be achieved by incorporating new technologies in the production processes of existing products or by creating new processes. As a result, the export penetration of European products in the Chinese market can be expected to increase.

Figure 1.5: EU-China Terms of Trade (ToT)



Source: JRC calculations from ITPD-E

Figure 1.6: EU-China trade classified by the level of tech-intensity: Chinese exports to the EU (1st panel), EU exports to China (2nd panel)



Source: JRC elaboration using COMTRADE database

FRAMEWORK CONDITIONS FOR EU COMPANIES IN CHINA

2.1 The regulatory framework in China has been improving, but future progress is still uncertain

The regulatory framework has been a longstanding issue for European companies operating in or considering an expansion into the Chinese market. In response to these recurring concerns, China launched a number of reforms set to improve its market access and relax some regulations. A recent example is the Foreign Investment Law (FIL) that aims to increase the regulatory transparency of the Chinese market. The recent legislative changes respond to concerns voiced by foreign businesses operating in China about how action to open up the Chinese market has been very selective and slow. With the COVID-19 outbreak and an unprecedented drop in demand, this negative sentiment is likely to become even more widespread.

European companies have been attracted to the Chinese market due to its size and potential for further development. However, the lack of market reforms and preferential treatment for SOEs negatively affected European investors. Therefore, 54% of the respondents to a survey in 2022 by the European Chamber of Commerce (ECC) in China expect more regulatory obstacles in the next five years.

2.2 China's FDI conditions remain less favourable than those of the EU

Chinese restrictions on FDI continue to be much stronger than those of the EU (Figure 2.1). However, there is a glimpse of hope, as China has started to open up its markets in some sectors by inviting more foreign insurance providers, banks and other financial service companies (Bloomberg, 2020). Moreover, compared to 2017, FDI restrictions in China have been reduced in other sectors, including electricity, transport, agriculture and forestry and real estate. Furthermore, the removal of foreign ownership limits in foreign-invested future companies (CSRC, 2020) signalled further improvement in market access in the financial service sector.

Overall, IP protection still points to the advantageous position of Chinese firms. The FIL emphasises the further strengthening of IP protection for foreign investors. In particular, the law emphasises 'voluntary and fair' technology collaboration between foreign investors and Chinese parties and implies stricter protection against infringement of foreign IP (Tsoi and Yan, 2019).

2.3 Minor changes in the framework conditions for business

The latest business confidence survey published by the ECC in China in 2022 details the obstacles and challenges facing foreign companies operating in China. The main obstacles include regulatory challenges and lack of market access; unsatisfactory levels of IPR protection; unequal treatment of foreign companies; and the preferential position of SOEs, including discrimination against foreign companies in public procurement procedures (Figure 2.2).

Ambiguous rules and regulations remain a major concern. 40% of the EU companies operating in China listed this problem among the three most significant regulatory obstacles in the Chinese market in the 2022 business confidence survey. However, around 47% of respondents to the 2021 survey put this obstacle at the top of their concerns. Overall, the share of respondents listing this obstacle as one of the main ones has remained rather high in recent years (46% in 2020 and 48% in 2019).

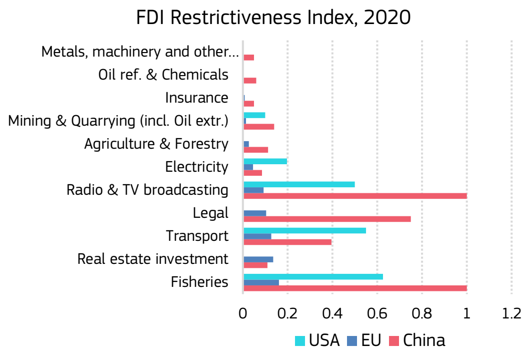
Similar concerns were voiced by the representatives of US government agencies and companies. Despite modest improvements in the business environment due to the FIL, the Chinese market remains hard for foreign firms to access. In particular, US firms have voiced concerns about a number of persistent market access restrictions, including ownership caps and requirements to form venture partnerships with local firms, industrial policies that subsidise domestic production (e.g. MIC2025) and mandatory technology transfers. Some of these restrictions have been relaxed following the implementation of the FIL in January 2020. However, the real effect of this recent legislative change is yet to be seen. In the meantime, current industrial policies effectively protect Chinese enterprises, especially the SOEs, from foreign competitive pressure (United States Department of State, USDS, 2020). In fact, the issue of unequal market access and preferential treatment of Chinese SOEs has been at the centre of the recent US-China trade tensions.

2.4 EU small and medium-sized enterprises feel more unwelcome than domestic Chinese companies

Despite the recent legislative initiative to liberalise foreign firms' access to the Chinese market, EU companies operating in China still perceive unfavourable treatment (Figure 2.3). The main areas of unequal treatment raised by respondents to the 2022 survey still include market access, communication with the government and public procurement (Figure 2.4).

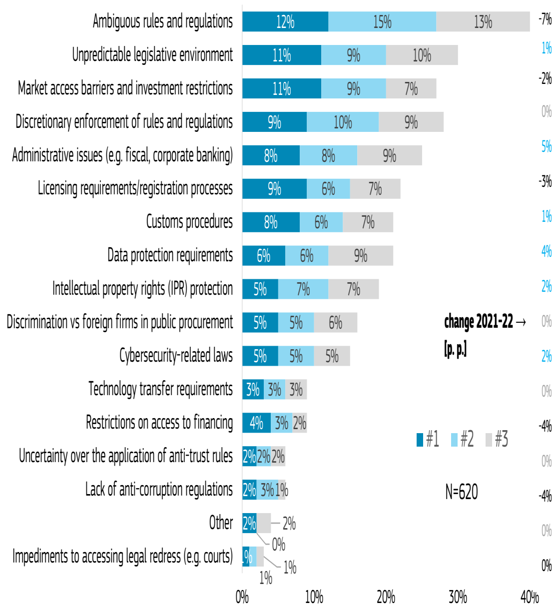
Moreover, the results of the 2020 survey highlight that small and medium-sized enterprises (SMEs) are more likely to report instances of unequal treatment (45%) compared to large companies with 1 000 or more employees (36%).

Figure 2.1: Chinese FDI restrictions are still high with respect to those of the EU and the US



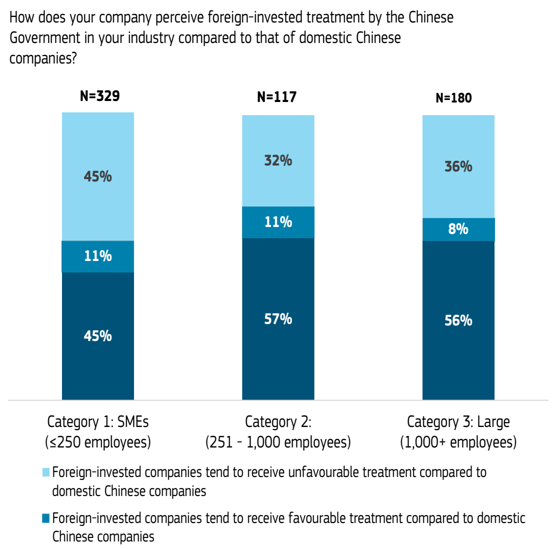
Source: FDI Restrictiveness Index – OECD, 2019

Figure 2.2: Top Regulatory Obstacles



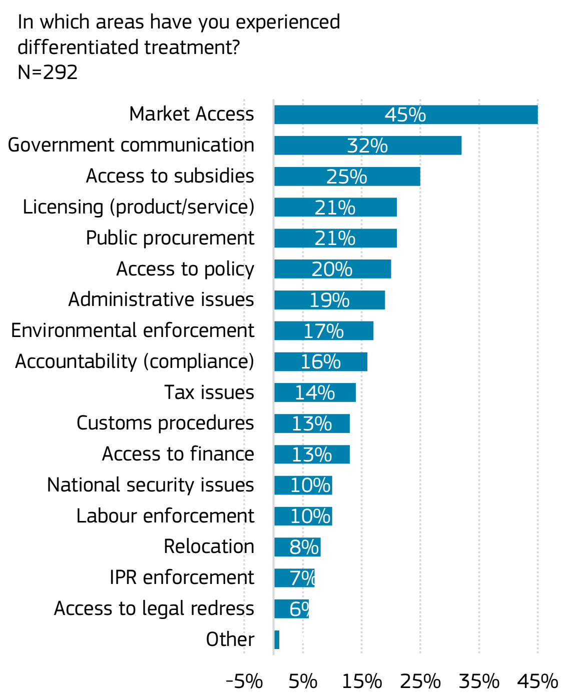
Source: European Chamber of Commerce in China, 2022

Figure 2.3: Rates of unfavourable treatment among different types of foreign invested companies



Source: European Chamber of Commerce in China, 2020

Figure 2.4: Rates of unfavourable treatment among different areas



Source: European Chamber of Commerce in China, 2022

Indeed, due to their small size SMEs usually lack the tools to affect the business environment: they cannot participate in shaping new legislation and programmes and have few chances to influence local decision-makers. At the same time, EU SMEs play an important role in the Chinese economy. Data from the Chinese National Bureau of Statistics show that in 2018 SMEs constituted 99.8% of the total number of firms in China and employed 79.4% of the workforce (China Daily, 2019). The ECC survey indicates that, among companies operating in China, EU SMEs display the highest share of companies with a large negative impact from financial challenges compared to large companies (ECC, 2020).

2.5 Persistent problems with IP infringement and other obstacles for European high-tech firms in China

In recent decades, China has successfully transformed from a global low-cost producer into one of the world's leading suppliers of high-tech products and services. Currently, around 40% of ECC members consider the Chinese market to be more innovative than the global average (ECC, 2022).

At the same time, numerous issues remain. First, 58% of ECC members report problems in finding suitable talent. The situation is deteriorating, as a consequence of the COVID-19 pandemic. Second, European R&D-intensive firms still report issues related to IP infringement. Despite recent legislative changes aimed at improving IP protection, around 46% of ECC members still rate IPR enforcement as 'inadequate' (ECC, 2022).

In fact, risks of IP infringement remain one of the main reasons behind the unwillingness of EU firms to bring their newest technological developments to China, with 40% of the respondents reporting IP infringement cases within last year (ECC, 2022). At the same time, the issue of compulsory technology transfer has been improving, with only 14% (compared to 16% in 2021) of ECC members reporting instances of compulsory technology transfer in return for market access (ECC, 2022).

Finally, despite some positive regulatory changes, European high-tech firms still struggle with various aspects of the Chinese business environment that seem to focus largely on shielding domestic producers from foreign rivals.

2.6 Several foreign companies plan to cut their operating costs in China due to COVID-19

Foreign businesses have always been lured into the Chinese market by its size and growth potential. However, several recurring issues, such as lack of transparent regulation, problems with IP protection and preferential treatment of domestic producers, have led to a widespread negative sentiment among EU businesses and investors.

As reported in recent business surveys, regulatory ambiguity, unpredictable legislation, and discretionary enforcement of the existing laws remain the most common obstacles for foreign businesses operating in or considering expanding into China. And, while China has recently tried to address some of these concerns by introducing a number of legislative changes aimed at improving the business environment, the enforcement of these measures seems to be slow and scattered, as many European companies continue to report cases of IP infringement and compulsory technology transfers.

Chinese regulators therefore need to take more decisive action to ensure a competitive and transparent business environment for all market players, regardless of their origin. As a global leader in technological development, China could shift the focus of its domestic IP-related policies from discriminating in favour of domestic producers to establishing a level playing field and promoting a fair and competitive environment for all market actors.

EU-CHINA IMPORT DEPENDENCE AT PRODUCT LEVEL

3.1 The COVID-19 outbreak led to supply distortions originating in China

The COVID-19 outbreak in early 2020 led to supply distortions such as the global transmission of value chain disruptions originating in China (Baldwin and Freeman, 2020) and the scarcity of critical medical goods coupled with increased export restrictions in producing countries (Leibovici and Santacreu, 2020).

These developments prompted a debate on whether economies should turn inwards to better deal with similar challenges in the future (Baldwin and Evenett, 2020), particularly in manufacturing value chains, to deal with increasing competition from China (Marschinski and Martínez-Turégano, 2020a and 2020b).

The share of total imports to the EU that come from China can indicate whether China alone could disrupt the supply of certain products[7], particularly those that have a high degree of EU import dependence[8], namely 50% or above of total supply. This definition follows one of the measures previously used by the Commission to identify (strategic) import dependence[9].

The import value of highly dependent products accounts for slightly more than 30% of total EU imports, but for almost 50% of the value of all imports from China. This means that in cases where the supply in the EU relies more on imports, China is a key supplier of many products (Figure 3.1[10]).

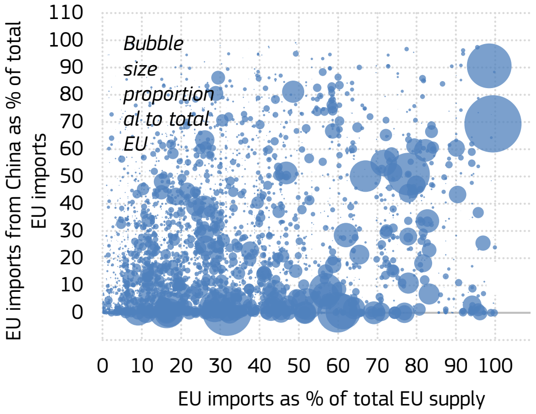
This is more pronounced for goods for which the overall import dependence is very high (i.e. 75% or more of total supply), a condition that is fulfilled by 30% of the import value from China, in contrast to 15% of total EU imports. Within this group of products, imports from China reach almost 50% of total imports, more than doubling the average figure for all goods considered.

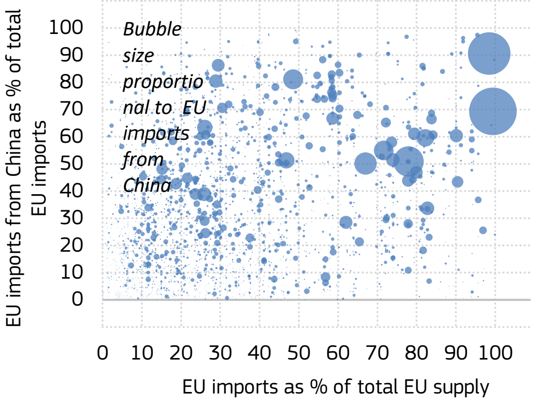
EU import dependence is very high for certain electronic products, while, among transport equipment, it is high for aircraft-related categories but moderate for motor cars (Tables 3.1 and 3.2[11]). These electronic products are important for the digital transition and their dependence can be considered as strategic. On the other hand, the share of EU imports from China is very large for electronic products, in which overall dependence is high, but lower within the group of transport equipment.

This is particularly the case for categories of consumer electronics such as cellular phones (HS code 851712) and laptops (847130), for which overall dependence is close to 100% and imports come overwhelmingly from China, which also has a dominant position in global markets.

Among the other products with large import values included in Table 3.1, EU import dependence is moderately high in most cases (above 60% for copper ores and soy-bean oilcakes – mainly used for animal feed), but the share of imports from China is generally limited, except for mixed plastic articles. This rather limited share can also be observed for both medicaments (HS code 300490) and instruments with medical and surgical purposes (901890), for which China´s global market share is very small.

Figure 3.1: EU overall import dependence as percentage of total EU supply and share of China in total EU imports (2017)





Source: JRC own elaboration based on Eurostat´s PRODCOM and UN´s COMTRADE

3.2 High import dependence in consumer electronics and apparel from China while the EU relies on other suppliers for transport equipment and medicaments

Most goods with the highest weight in EU total imports belong to two product groups: electronics and transport equipment, including both final products and related parts or components[12]. When ranking products by the degree of EU import dependence (i.e. imports as percentage of total supply), the same categories including cellular phones and laptops remain in the top 25 (Table 3.2). Most products in such a ranking belong again to a limited number of categories, of which the most significant is apparel[13].

In particular, most categories consisting of garments are characterised by a high import dependence (above 80% of EU total supply), a high share of imports from China (close to 70% in some cases) and by China being the largest exporter in global markets (with a share in the 40-50% range).

The overall EU import dependence is also very high for wristwatches, rubber gloves and certain categories of crude vegetable oils, metal ores, precious stones and electronic products. Of these, only electronic products have a significant import share from China, above 40% for certain data storage devices and 60% for the group covering printing machinery[14], with China having a medium to high share of the global market in the second case (close to 40%).

3.3 A large share of EU imports strongly depend on China, which has a large global market share for many of these goods

There is a strong positive correlation between China's share of total EU imports and China's share of world exports. This is a proxy for global market power that can aggravate import dependence (Figure 3.2[15]).

A correlation coefficient of 0.66 across more than 4 000 products suggests a clear correspondence between China´s trade specialisation and the geographical origin of EU imports. Product categories with a high share of EU import dependence on China (50% or more of total imports) represent 20% of the overall value of EU imports, and 55% of total imports from China. Furthermore, China's average global export share is close to 50% for these products.

Table 3.1: Top 25 products by value in EU total imports (2017)

HS code	HS product	EU total imports (million USD)	EU imports as % of total EU supply	EU imports from China as % of total EU imports	China exports as % of world exports
851712	Telephones for cellular networks "mobile telephones" or for other wireless networks	43,499	99.4	69.3	53.5
300490	Medicaments consisting of mixed or unmixed products for therapeutic or other purposes	32,872	31.7	0.7	0.9
847130	Data-processing machines, automatic, portable, weighing <= 10 kg	26,600	98.5	90.6	71.5
851762	Machines for the reception, conversion and transmission or regeneration of voice, images etc.	24,180	77.9	50.9	26.8
880240	Aeroplanes and other powered aircraft of an of an unladen weight > 15.000 kg (excl. helicop.)	21,604	59.8	0.2	0.4
870332	Motor cars and other motor vehicles principally designed for the transport of persons	18,761	16.3	1.2	0.2
841112	Turbojets of a thrust > 25 kN	16,563	61.3	0.4	5.0
854231	Electronic integrated circuits as processors and controllers, combined / not with other circuits	14,852	56.8	8.4	13.1
841191	Parts of turbojets or turbopropellers, n.e.s.	13,361	52.0	3.2	4.2
847330	Parts and accessories of automatic data-processing machines	13,230	67.0	50.2	31.4
880330	Parts of aeroplanes or helicopters, n.e.s. (excl. those for gliders)	12,662	28.5	2.2	1.8
870322	Motor cars and other motor vehicles principally designed for the transport of persons	11,031	16.9	0.1	2.4
870323	Motor cars and other motor vehicles principally designed for the transport of persons	10,788	9.1	0.6	1.3
854239	Electronic integrated circuits (excl. such as processors, controllers, memories and amplifiers)	9,818	56.8	6.3	5.8
852990	Parts suitable for transmission and reception apparatus for radio-broadcasting or TV	9,397	71.6	55.0	26.6
901890	Instruments and appliances used in medical, surgical or veterinary sciences, n.e.s.	7,964	43.7	7.6	3.3
847170	Storage units for automatic data-processing machines	7,909	62.0	28.5	25.3
844399	Parts and accessories of printers, copying machines and facsimile machines, n.e.s.	7,387	82.7	33.7	14.5
260300	Copper ores and concentrates	6,930	69.1	0.0	0.0
850440	Static converters	6,907	46.8	51.3	32.8
760120	Unwrought aluminium alloys	6,901	51.6	0.1	4.9
847150	Processing units for automatic data-processing machines	6,851	82.2	59.6	27.6
392690	Articles of plastics and articles of other materials of heading 3901 to 3914, n.e.s	6,796	25.9	38.9	19.2
854430	Ignition wiring sets and other wiring sets for vehicles, aircraft or ships	6,702	42.9	1.1	7.9
230400	Oilcake and other solid residues	6,552	64.1	1.7	1.9

Note: White cells correspond to figures equal or lower than 25% and the darkest blue to figures equal or higher than 75%.
Source: JRC own elaboration based on Eurostat´s PRODCOM and UN´s COMTRADE

Table 3.2: Top 25 products of EU total imports with the highest degree of import dependence relative to total EU supply (2017)

HS code	HS product	EU total imports (million USD)	EU imports as % of total EU supply	EU imports from China as % of total EU imports	China exports as % of world exports
720310	Ferrous products obtained by direct reduction of iron ore, in lumps, pellets or similar forms	738	99.7	0.0	0.4
851712	Telephones for cellular networks "mobile telephones" or for other wireless networks	43,499	99.4	69.3	53.5
151311	Crude coconut oil	829	98.9	0.0	0.0
847130	Data-processing machines, automatic, portable, weighing <= 10 kg	26,600	98.5	90.6	71.5
640411	Sports footwear, incl. tennis shoes, basketball shoes, gym shoes, training shoes and the like, w	3,075	96.9	25.6	5.8
151110	Crude palm oil	3,014	96.1	0.0	0.0
910221	Wrist-watches, whether or not incorporating a stop-watch facility, with automatic winding	2,248	95.7	1.1	1.4
910211	Wrist-watches, electrically operated, with mechanical display only	1,660	95.7	36.8	14.9
401519	Gloves, mittens and mitts, of vulcanised rubber (excl. surgical gloves)	889	94.2	8.9	6.1
401511	Surgical gloves, of vulcanised rubber (excl. fingerstalls)	529	94.2	2.8	18.1
710239	Diamonds, worked, but not mounted or set (excl. industrial diamonds)	4,686	94.1	2.9	1.7
710391	Rubies, sapphires and emeralds, worked, whether graded /not, but not strung, mounted or set	529	94.1	0.3	0.0
621050	Women / girls garments of textile fabrics, rubberised, impregnated, coated, covered, laminated	844	94.0	59.0	39.0
621040	Men / boys garments of textile fabrics, rubberised, impregnated, coated, covered, laminated	751	94.0	54.9	46.3
261400	Titanium ores and concentrates	668	93.8	0.0	1.0
910121	Wrist-watches of precious metal or of metal clad with precious metal, with automatic winding	938	91.8	0.2	0.2
910111	Wrist-watches of precious metal, electrically operated, with mechanical display only	549	91.8	0.7	0.1
260600	Aluminium ores and concentrates	707	90.7	11.1	0.3
852351	Solid-state, non-volatile data storage devices for recording data from an external source	4,088	90.4	43.4	10.9
844331	Machines with two or more of the functions of printing, copying or facsimile transmission	3,864	90.1	60.4	37.0
611610	Gloves, mittens, mitts, impregnated, coated, covered with plastics / rubber, knitted or crochete	712	88.2	54.4	49.8
620193	Men / boys anoraks, windcheaters, wind jackets and similar articles, of man-made fibres	1,974	84.1	60.6	46.9
620293	Women / girls anoraks, windcheaters, wind jackets and similar articles, of man-made fibres	2,219	83.8	66.5	54.4
620213	Women / girls overcoats, raincoats, car coats, capes, cloaks and similar, of man-made fibres	979	83.8	68.7	39.0
610910	T-shirts, singlets and other vests of cotton, knitted or crocheted	5,916	83.2	6.9	17.3

Note: White cells correspond to figures equal or lower than 25% and the darkest blue to figures equal or higher than 75%. %; only product categories with import value of USD 500mn or higher are considered.
Source: JRC own elaboration based on Eurostat´s PRODCOM and UN´s COMTRADE

Most of the products with the highest value shares of EU imports from China (i.e. those with the highest total value of EU imports) belong to the group of electronic products[16] (Table 3.3 and 3.4). Among these, final goods such as cameras, multifunction printers and flash memory cards[17] simultaneously show (i) a high import dependence (80% or more of total supply); (ii) a high share of imports from China (40% or above); (iii) and a high (but not above average) global market share of China for these products. There is also a substantial supply from China of general-purpose electronic inputs such as printed circuits[18] but the EU's dependence is limited overall.

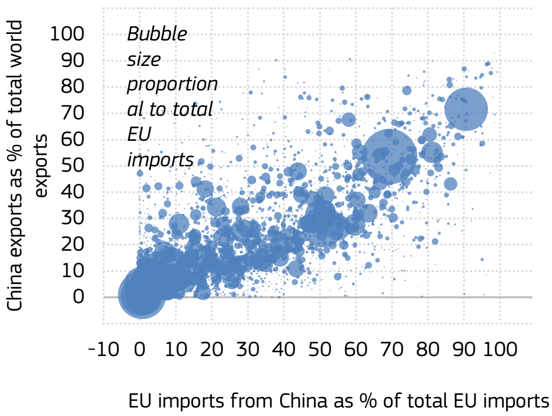
Among other products shown in Table 3.3, categories within apparel, travelling bags and wheeled toys display high scores on all three dimensions – (i) to (iii) - mentioned in the previous paragraph, while China's import dominance (rather than dependence) is detected for electric lamps and mixed categories of plastic and iron goods.

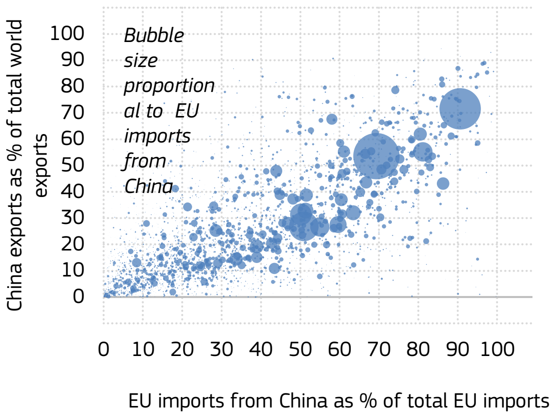
The EU's exposure to China is more limited when considering only goods for which the import dependence on China is extremely high (i.e. 75% or more of total supply). This is the case for only 5% of total EU imports by value but the dependence is intensified by the dominant position of China in global markets, with an average share above 60% of world exports.

Looking at the top 25 product categories by their degree of EU import dependence on China (Table 3.4) and with (i) a share of imports from China above 85% of total EU imports and (ii) a Chinese global market share of 70% of world exports on average, all but two categories (laptops and ceiling/wall electric lamps) correspond to goods with relatively low import values (between USD 100 million and 1 billion). Goods matching these criteria are therefore very diverse and belong to various product classes.

Among products for which overall EU import dependence is very high (75% or above), we find leisure goods (such as electric lighting sets for Christmas trees, fireworks or artificial flowers) and household appliances (weighing machines or radio and sound reproducing apparatus), while a more moderate but still high degree of dependence (between 50% and 75%) is observed for umbrellas, electrothermic appliances (e.g. toasters), and manganese and magnesium products. For none of the remaining products is the EU's overall import dependence lower than 20% of total supply.

Figure 3.2: EU import dependence on China as percentage of total EU imports and world export share of China (2017)





Source: Eurostat´s PRODCOM and UN´s COMTRADE

Table 3.3: Top 25 products by value of EU imports from China (2017)

HS code	HS product	EU imports from China (million USD)	EU imports as % of total EU supply	EU imports from China as % of total EU imports	China exports as % of world exports
851712	Telephones for cellular networks "mobile telephones" or for other wireless network	30,163	99.4	69.3	53.5
847130	Data-processing machines, automatic, portable, weighing <= 10 kg	24,106	98.5	90.6	71.5
851762	Machines for the reception, conversion and transmission or regeneration of voice, ir	12,306	77.9	50.9	26.8
847330	Parts and accessories of automatic data-processing machines or for other machine	6,636	67.0	50.2	31.4
950300	Tricycles, scooters, pedal cars and similar wheeled toys	5,303	48.6	81.1	55.2
852990	Parts suitable for transmission and reception apparatus for radio-broadcasting or T'	5,165	71.6	55.0	26.6
847150	Processing units for automatic data-processing machines	4,083	82.2	59.6	27.6
850440	Static converters	3,544	46.8	51.3	32.8
853400	Printed circuits	3,163	26.1	63.4	32.0
392690	Articles of plastics and articles of other materials of heading 3901 to 3914, n.e.s	2,645	25.9	38.9	19.2
844399	Parts and accessories of printers, copying machines and facsimile machines, n.e.s.	2,488	82.7	33.7	14.5
851770	Parts of telephone sets, telephones for cellular networks or other wireless network	2,468	73.9	51.5	38.7
940540	Electric lamps and lighting fittings, n.e.s.	2,431	28.9	80.5	61.9
844331	Machines with two or more of the functions of printing, copying or facsimile transm	2,334	90.1	60.4	37.0
847170	Storage units for automatic data-processing machines	2,255	62.0	28.5	25.3
852580	Television cameras, digital cameras and video camera recorders	2,215	79.9	46.9	28.1
940510	Chandeliers and other electric ceiling or wall lighting fittings	2,198	29.5	86.3	43.1
420292	Travelling-bags, insulated food / beverage bags, toilet bags, shopping-bags, etc.	2,112	58.6	66.7	43.6
640419	Footwear with outer soles of rubber or plastics and uppers of textile materials	2,110	79.4	61.1	55.3
611030	Jerseys, pullovers, cardigans, waistcoats and similar articles, of man-made fibres	2,031	77.8	43.9	47.9
732690	Articles of iron or steel, n.e.s. (excl. cast articles or articles of iron or steel wire)	1,820	23.7	38.9	15.1
854442	Electric conductors for a voltage <= 1.000 V, insulated, fitted with connectors, n.e.s.	1,785	15.2	48.1	37.3
848180	Appliances for pipes, boiler shells, tanks, vats or the like	1,778	18.7	42.7	20.4
852351	Solid-state, non-volatile data storage devices to record data from external source	1,775	90.4	43.4	10.9
640299	Footwear with outer soles and uppers of rubber or plastics	1,716	73.6	58.0	67.6

Note: White cells correspond to figures equal or lower than 25% and the darkest blue to figures equal or higher than 75%.
Source: JRC own elaboration based on Eurostat´s PRODCOM and UN´s COMTRADE

Table 3.4: Top 25 products of EU imports from China with the highest degree of import dependence relative to total EU imports (2017)

HS code	HS product	EU imports from China (million USD)	EU imports as % of total EU supply	EU imports from China as % of total EU imports	China exports as % of world exports
940530	Electric lighting sets of a kind used for Christmas trees	266	95.4	97.5	85.4
360410	Fireworks	253	77.4	96.8	89.0
670210	Artificial flowers and articles made of artificial flowers, foliage or fruit	238	91.8	96.3	88.7
871500	Baby carriages and parts thereof, n.e.s.	439	49.2	95.1	58.5
640110	Waterproof footwear incorporating a protective metal toecap	126	32.1	95.0	14.4
670290	Artificial flowers and articles made of artificial flowers, foliage or fruit	213	91.8	95.0	84.6
810411	Unwrought magnesium, containing >= 99,8% by weight of magnesium	172	57.9	94.8	79.7
660199	Umbrellas and sun umbrellas, incl. walking-stick umbrellas	117	72.7	94.6	83.8
851672	Electric toasters, for domestic use	142	56.1	93.3	83.4
852713	Radio-broadcast receivers capable of operating without external power	150	91.3	90.8	69.8
660191	Umbrellas having a telescopic shaft (excl. toy umbrellas)	104	72.7	90.7	83.9
847130	Data-processing machines, automatic, portable, weighing <= 10 kg	24,106	98.5	90.6	71.5
842310	Personal weighing machines, incl. baby scales; household scales	168	88.9	90.5	67.2
660110	Garden or similar umbrellas (excl. beach tents)	252	72.7	90.5	74.5
630140	Blankets and travelling rugs of synthetic fibres	352	65.4	90.1	86.9
960340	Paint, distemper, varnish or similar brushes, paint pads and rollers	128	22.2	89.7	60.9
811100	Manganese and articles thereof, n.e.s.; manganese waste and scrap	233	57.9	89.7	75.2
810419	Unwrought magnesium, containing < 99,8% by weight of magnesium	146	57.9	89.6	61.0
961700	Vacuum flasks and other vacuum vessels, and parts thereof	163	31.9	89.4	75.5
293624	D-Pantothenic or DL-pantothenic acid "Vitamin B3 or B5" and their derivatives	152	39.6	88.5	68.8
851679	Electro-thermic appliances, for domestic use	732	56.1	88.3	61.2
871190	Side cars for motorcycles	178	39.4	87.1	50.8
820551	Household hand tools, non-mechanical, with working parts of base metal, n.e.s.	198	45.4	87.0	58.2
940520	Electric table, desk, bedside or floor-standing lamps	594	60.0	86.5	65.3
940510	Chandeliers and other electric ceiling or wall lighting fittings	2,198	29.5	86.3	43.1

Note: White cells correspond to figures equal or lower than 25% and the darkest blue to figures equal or higher than 75%; only product categories with import value of USD 100mn or higher are considered.
Source: JRC own elaboration based on Eurostat´s PRODCOM and UN´s COMTRADE

EU VULNERABILITY TO SHORTAGES OF COVID-19-RELATED GOODS

4.1 Resilience in EU global value chains

The COVID-19 pandemic has led to a new debate[19] about global value chains (GVCs), trying to understand whether the excessive globalisation and fragmentation of production has created new economic vulnerabilities[20]. This chapter analyses the EU's vulnerability to shortages of COVID-19-related goods, given its trade interdependence worldwide.

The analysis has been made by using a unique trade statistics database (2018 data, the latest available) in which, unlike similar databases, bilateral trade flows at a very detailed level (8 digits) have been adjusted to account for the correct (producer) country of origin of the goods traded. The analysis will be extended by using more recent data (up to August 2020), provided by the surveillance statistics, to give a general picture of the EU's dependence on imports, in particular from China, before and during the pandemic.

The resilience of supply chains is a crucial ingredient in securing strategic autonomy and guaranteeing that the EU will maintain its global leadership. This analysis focuses on the short run and aims to identify vulnerable supply chains of COVID-19 goods, as identified by the World Customs Organization (WCO)[21]. A broad range of COVID-19 goods is included, covering not only medical equipment and medicines but also other goods to protect healthcare professionals and other people from infection, such as plastic gloves or face masks and other protective garments[22].

4.2 EU trade in COVID-19-related goods is concentrated on a few countries and a few products

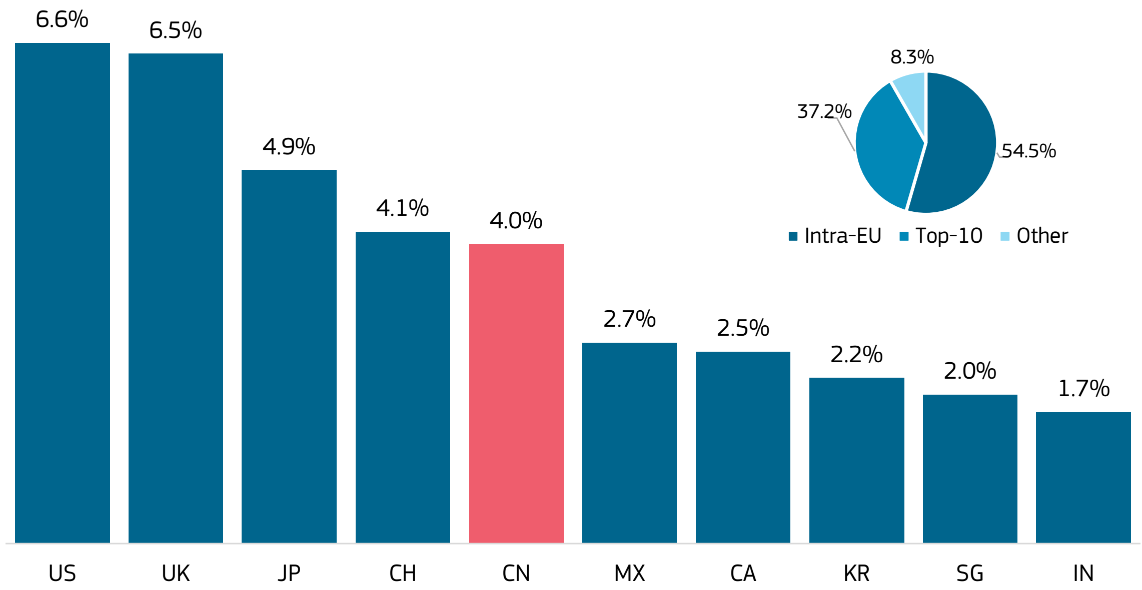
Almost two thirds of global exports of COVID-19-related goods come from the EU (34.9%), China (10.2%), the US (10%), Switzerland (6.8%) and Japan (4.6%). Similarly for imports, where the top five countries represent 70.5% of the global imports of COVID-19-related goods: the EU (36.7%), the US (19.8%), China (5.8%), the UK (5.1%) and Japan (3.1%).

Figure 4.1 shows the top 10 non-EU countries that export most COVID-19-related goods to the EU. While most of the EU goods imported by EU Member States come from other Member States (intra-EU trade 54.5%), 10 non-EU countries together account for an additional 37.2% of imported goods. These are the US (6.6%), the UK (6.5%), Japan (4.9%), Switzerland (4.1%), China (4.0%), Mexico (2.7%), Canada (2.5%), South Korea (2.2%), Singapore (2.0%) and India (1.7%).

Figure 4.2 shows the types of COVID-19-related goods most frequently imported by EU Member States, both from other Member States or from outside the EU. It covers 27.7% of all EU imports of COVID-19-related goods. Medicaments rank first with 12.2% followed by immunological products (not used for COVID-19 test kits in 2018) with 5.6%. Next, 2.2% correspond to urine bags, body bags, plastic face shields and plastic (and rubber) overshoes, followed by instruments and appliances for surgery and medical services (2%); needles, catheters, cannulae and the like (1.7%) and diagnostic reagents (1%).

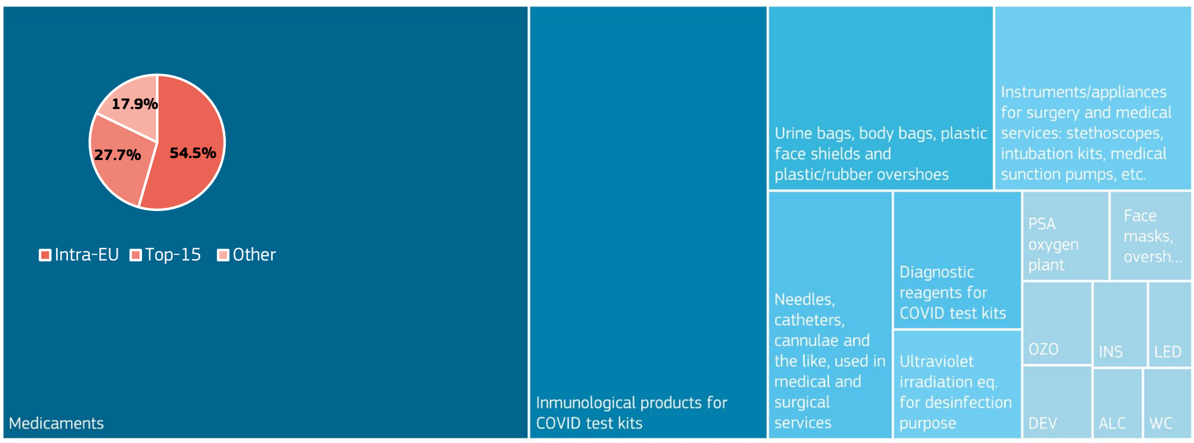
With less than 1%: ultraviolet irradiation equipment for disinfection purposes; oxygen therapy equipment; pulse oximeters, monitoring devices and laryngoscopes; diagnostic test instruments and apparatus; LED lamps; alcohol solutions and protective garments for surgical/medical use, among others.

Figure 4.1: Top 10 non-EU partners exporting COVID-19 related goods to the EU



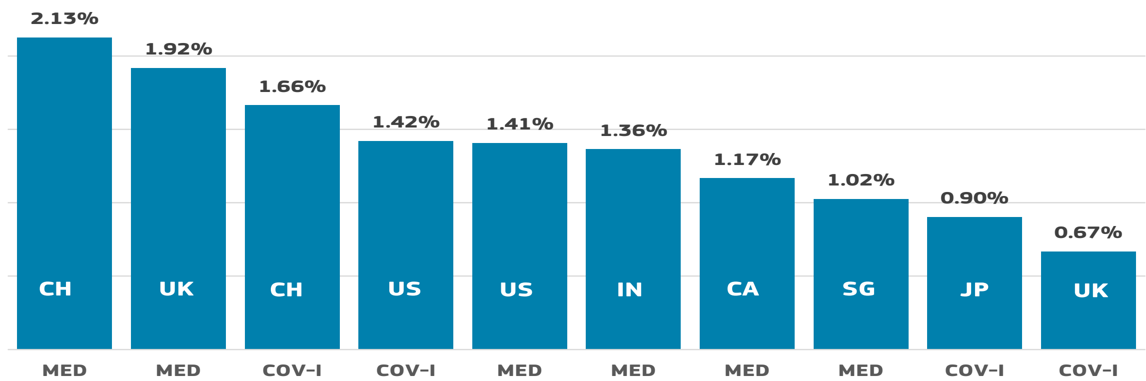
Source: Eurostat and JRC calculations

Figure 4.2: Top 15 of COVID-19 related goods imported by the EU (% import share)



Note: See endnotes for acronyms[23].
Source: Eurostat and JRC calculations

Figure 4.3: Top 10 of COVID-19 related goods imported by the EU



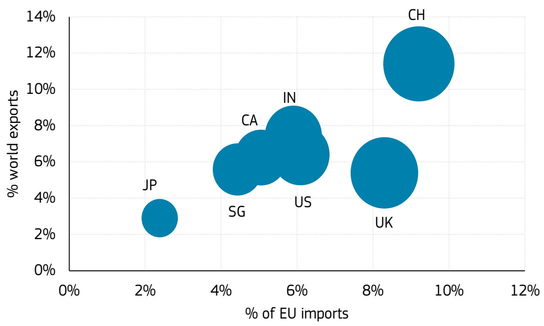
Note: MED = medicaments; COV-I = Immunological products for COVID test kits.
Source: Eurostat and JRC calculations

Table 4.1: Top 15 imported COVID-19 related goods and the level of world market concentration

Order	Product	Description	HH	Degree	Top-country
13	85395000	Light-emitting diode "LED" lamps	0.52	high	CN
9	63079098	Face masks, overshoes and absorbent pads of non-woven textiles	0.29	high	CN
2	30021500	Inmunological products for COVID test kits	0.27	high	CH
14	22071000	Alcohol solution	0.23	moderate	US
6	38220000	Diagnostic reagents for COVID test kits	0.23	moderate	US
8	84213935	Pressure Swing Adsorption (PSA) oxygen plant	0.23	moderate	UK
1	30049000	Medicaments	0.20	moderate	CH
15	62105000	Women´s or unisex protective garments for surgical/medical use	0.19	moderate	CN
12	90278017	COVID-19 Diagnostic Test instruments and apparatus	0.17	moderate	US
3	39269097	Urine bags, body bags, plastic face shields, plastic/rubber overshoes	0.16	moderate	CN
10	90192000	Oxygen therapy equipment	0.14	low	CN
7	85437090	Ultraviolet irradiation eq. for desinfection purpose	0.13	low	CN
5	90183900	Needles, catheters, cannulae and the like	0.13	low	MX
4	90189084	Instruments/appliances for surgery and medical services	0.13	low	US
11	90181990	Pulse oximeters, monitoring devices and laryngoscopes	0.12	low	JP

Source: Eurostat and JRC calculations

Figure 4.4: EU imports of medicaments and main suppliers



Source: Eurostat and JRC calculations

As shown in Figure 4.3, medicaments and immunological products imported from Switzerland, the US and the UK were the COVID-19-related goods most frequently imported into the EU. Although the trade data is from 2018, almost two years before the COVID-19 outbreak, the EU already showed a high trade dependence on immunological products from Switzerland, the US, Japan and the UK. These products turned out to be crucial for the production of COVID-19 test kits.

4.3 The vulnerability of EU imports of specific COVID-19-related goods

In this section, we analyse whether EU imports of COVID-19-related goods are concentrated on a few countries with a dominant position in the world market, as a measure of vulnerability of supplies. Following Blengini et al. (2017), we have used the Herfindahl-Hirschmann Index (HH) as a proxy for country concentration.

Table 4.1 shows that the EU is highly vulnerable in the categories of LED lamps and face masks imported from China as well as immunological products imported from Switzerland. A moderate concentration in world exports of medicaments is also relevant given its high share of COVID-19-related imported goods (Figure 4.2). The following sections will pay special attention to the products identified as the most vulnerable for the EU, with a particular focus on EU-China trade.

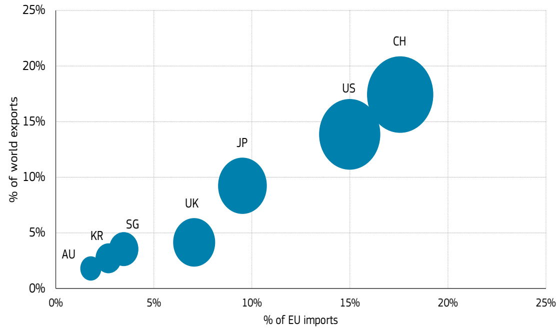
While 9.2% of EU imports of **medicaments** come from Switzerland, this country holds 11.2% of the global market sales. The UK's global market share of medicaments is not so high (5.4%) but it is the source of 8.3% of total EU imports of medicaments. These countries are followed by India and the US with 7.4 % and 6.4 % of the global market sales and each with around 6% of the EU imports of medicaments.

Figure 4.5 illustrates the case of **immunological products**, before the COVID-19 outbreak. Switzerland and the US dominate the global market, with a combined total of 32.5% of imports, while supplying the EU with roughly the same share of its imports. Japan and the UK come next with lower shares but are equally important from a strategic point of view. EU imports from other EU countries account for 41.4% of the total, of which Germany and Belgium account for half.

The case of **non-woven textile facemasks and other similar products** (absorbent pads, boot covers and overshoes, etc.) (Figure 4.6) shows a worrying vulnerability for the EU, as is the case for other countries[24]. In 2018, one third of all facemasks imported by EU countries came from China, which at that time supplied half the global market. EU countries also imported these products from each other, representing 34.5% of imports, mainly from Poland (8.5%) and Italy (4.7%). Because of China's temporary export ban in 2020, US firms such as 3M with factories in Shanghai had to sell all their production within China.

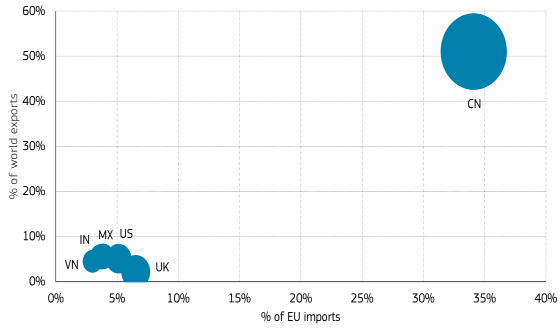
EU imports of **light-emitting diode (LED) lamps**, illustrated in Figure 4.7, show a similar trend to non-woven textile facemasks and other similar products (Figure 4.6).

Figure 4.5: EU imports of immunological products and main suppliers



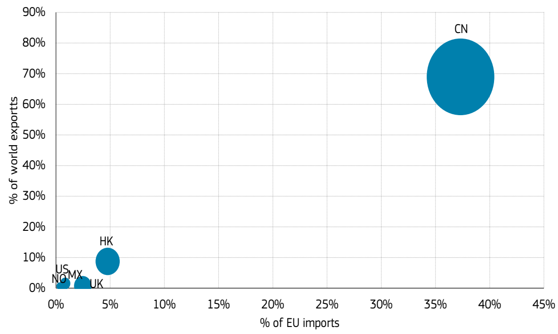
Source: Eurostat and JRC calculations

Figure 4.6: EU imports of non-woven textile face masks and other similar products and main suppliers



Source: Eurostat and JRC calculations

Figure 4.7: EU imports of Light-emitting diode "LED" lamps and main suppliers



Source: Eurostat and JRC calculations

China dominates the global LED market with 70% of total world exports, the second biggest exporter, Hong Kong, has just 8.7% of the market, while the remaining countries each have a share below 2%. China accounts for 37.3% of all the EU imports, followed by Hong Kong (4.8%) and the UK (2.5%). EU countries also imported 52.8% of these products from each other, mainly from Austria (12.2%) and France (4.7%).

China dominates the global market for **women´s or unisex protective garments for surgical/medical use** with a share of 23% (Figure 4.8), followed by Vietnam (15.1%). Looking at the, Chinese exports account for 17.4%, Vietnam for 11.4% and the UK for 4.4 % of all EU imports of these products. Total intra-EU trade accounts for 42.5%, mainly coming from Italy (8.4%) and Poland (6.3%).

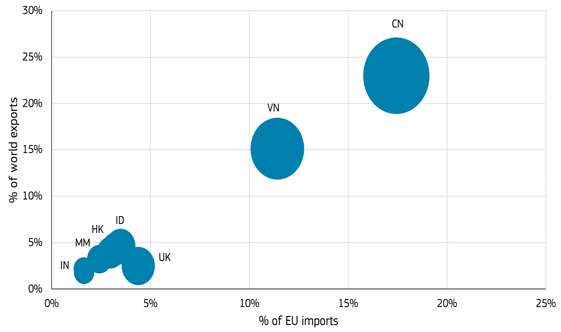
Figure 4.9 shows the situation for **rubber/plastic medical disposable goods**, the third most imported good by the EU with a share of 2.2% of all EU imports of COVID-19-related goods. Imports coming from other EU countries account for 52% of all the EU imports (the highest shares, of 5% each, come from Austria, France and Poland). More than one third of global exports come from China (22%) and the US (12%), with the former having almost a double market share. China provides 14% of all plastic-related medical consumables while the US provides 9%.

Figure 4.10 shows imports of **oxygen therapy equipment**. China and Singapore dominate the global market, with a combined total of 37.6% of exports while supplying 17.8% (China) and 10.6% (Singapore) of all EU imports. The US comes next, with a global market share of 8.3% and exporting to the EU roughly the same share of its imports. Within the EU, almost one third of all imports from one Member State to another come from Germany (around 10% of total imports).

The main suppliers to EU Member states of **Ultraviolet irradiation equipment** e.g. for disinfection purposes (Figure 4.11) are China (18.3% of imports), the UK (8.2%) and the US (7.9%).

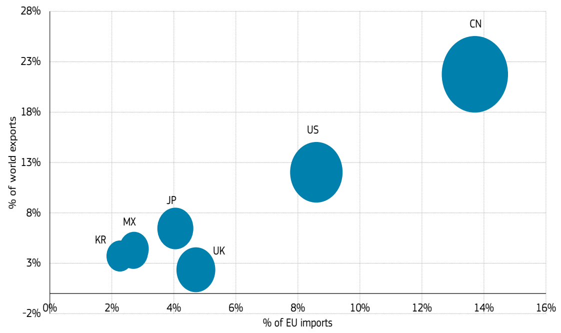
While China and the US lead the global market in devices for disinfection purposes, with almost 40% of global exports in total, the UK's global market share is the lowest of the top seven EU import partners. 38.4% of all imports are from one EU Member State to another, coming mainly from Hungary (4.5%), Austria (4.2%) and Spain (3.9%).

Figure 4.8: EU imports of Women´s or unisex protective garments for surgical/medical use and main suppliers



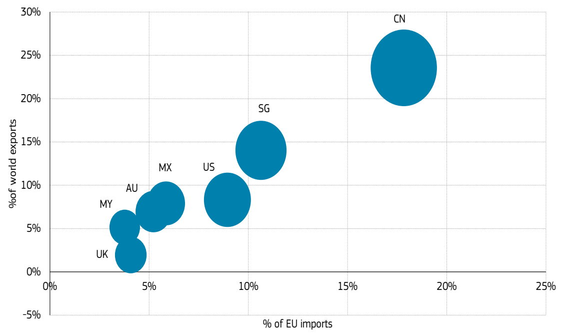
Source: Eurostat and JRC calculations

Figure 4.9: EU imports of Urine bags, body bags, plastic face shields and plastic/rubber overshoes and main suppliers



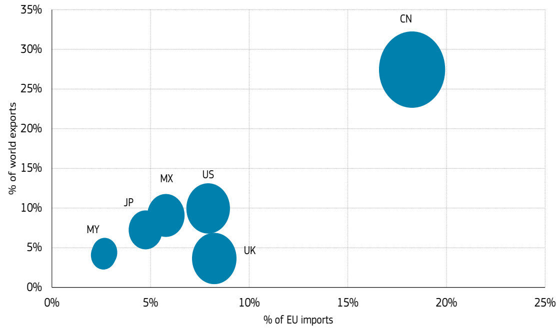
Source: Eurostat and JRC calculations

Figure 4.10: EU imports of oxygen therapy equipment and main suppliers



Source: Eurostat and JRC calculations

Figure 4.11: EU imports of Ultraviolet irradiation eq. for disinfection purpose and main suppliers



Source: Eurostat and JRC calculations

4.4 The EU supply chain for COVID-19-related goods has proven to be quite robust

The analysis carried out using 2018 data provides a picture of the situation before the COVID-19 pandemic and does not capture what the trade in COVID-19-related products looks like today. We have extended the analysis, considering China-EU trade in particular, using the latest available surveillance data from August 2019 to August 2020.

The indicators used are the shares of value (Euro) and the shares of quantity (tonnes and kilogrammes) of EU imports from China. We include the quantity imported since it can be misleading to look only at the value of imports. For example, one country tends to produce expensive and innovative products while others make cheaper and generic devices. This is what seems to be the case for medical devices - light-emitting diode (LED) lamps and ultraviolet irradiation (e.g. for disinfection purposes). While China was the top exporter to the EU in terms of both value and quantity during the whole period in question (with a peak of almost 75% in May 2020), at the end of August 2020 the US was in first place in terms of the value of imports to the EU while China was still the leading provider to the EU in terms of quantity.

Looking at face and eye protection, surveillance data confirm the vulnerability of the EU supply chain. From March 2020, China provided almost 95% of all EU imports by value and 90% in terms of volume. In the case of protective garments, China was the major supplier for the whole period, with 60% of EU imports on average for both indicators. On other goods considered, surveillance data do not allow for a proper disaggregation. However, considering the macro category of medical consumables, in terms of value, China and the US show the same average share of around 30%, while in terms of quantity China is the leading supplier to the EU with an average share of 55% of imports.

4.5 The EU is highly vulnerable to a break in supplies of LED lamps and facemasks imported from China

The EU turned out to be highly vulnerable to a break in supplies of LED lamps and facemasks imported from China. In 2018, China accounted for 37.3% of LED lamps, by volume, imported into the EU, while one in three facemasks imported by the EU came from China.

Surveillance statistics highlight the high level of the EU's dependence on China for these goods, which has been exacerbated by the COVID-19 pandemic. In May 2020 EU imports from China reached a peak of 75% of LED lamps and around 95% of facemasks. The same trend was also seen in 2020 for other COVID-19-related goods, for which the EU showed a moderate or low vulnerability in 2018[25].

ECONOMIC COMPLEXITY OF THE EU, CHINA AND THE US

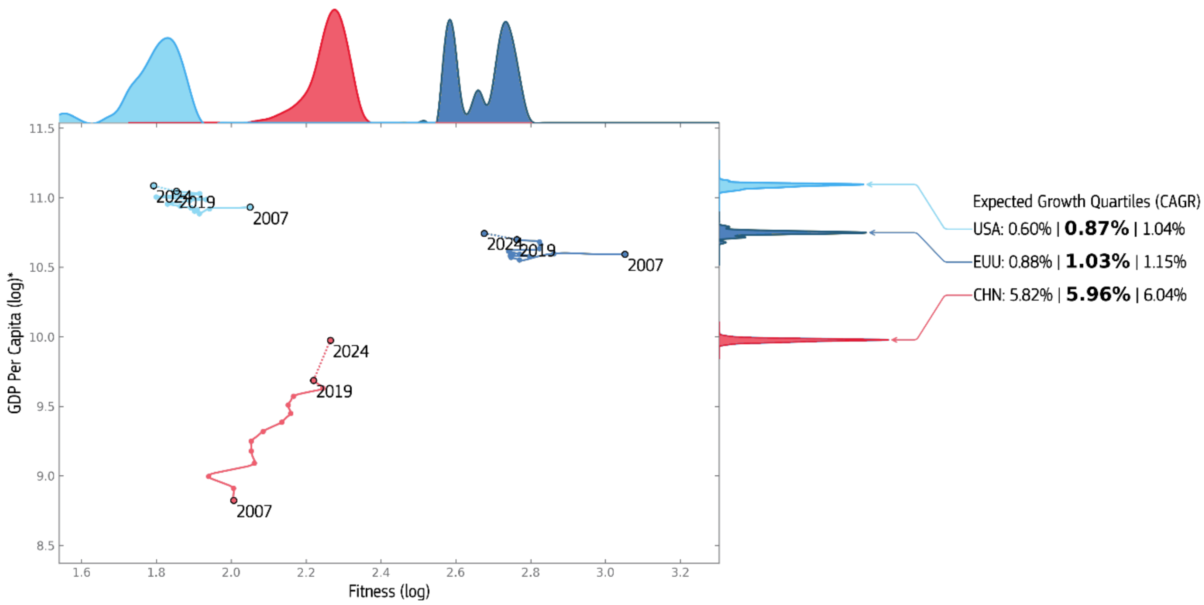
5.1 The EU ranks first in economic fitness, while China is expected to have higher GDP growth

The EU is the most diversified economy in the world in terms of competitively traded goods (2650 products), followed by China (2376 products) and the US (1776 products).

In terms of economic fitness (see Box 1) this ranking is unchanged, but with a LogFitness score of 2.89 the EU is further ahead of China (2.29) and the US (1.93) due to its more complex mix of products traded. This gap was closing in the early 2000s but stabilised around 2010 and hasn't diminished significantly since then.

Pre-COVID-19 growth estimates (Figure 5.1), in terms of GDP per capita at purchasing power parity, projected compound annual growth rates from 2018 to 2023 of 1.01% for the EU, 0.78% for the US and 6.04% for China. The relative uncertainty of the forecasts is small for all the three economies.

Figure 5.1: Fitness-GDPpc trajectories and forecasted growth distributions in terms of GDP Per Capita at Purchasing Power Parity (Pre-COVID-19 estimates)



Source: JRC computations based on EUROSTAT data

Box 1:

The economic complexity framework

Economic complexity combines network science and machine learning to provide accurate and detailed forecasts

Economic complexity is a framework building on earlier evolutionary and institutional literature (Hirschman, 1958; Cimoli & Dosi, 1995; Teece, et al., 1994) to analyse the complexity of economic systems. It describes the economy as an evolutionary process of globally interconnected ecosystems. The main recent advance on earlier literature is the use of newly developed approaches from network and complex dynamical systems science (Hausmann & Klinger, 2006; Hidalgo & Hausmann, 2009; Tacchella et al., 2012). The economic complexity framework shifts the focus of economic analysis from aggregate quantities (What is the GDP of the country? How many patents are published?) to their underlying components (In which industrial sectors do countries specialise? Which patents are published?), with the aim to provide complementary information compared to more conventional macroeconomic analysis. It offers the potential of discussing *quantitatively* several policy-relevant issues that otherwise would only be treated qualitatively, or by case studies.

The economic fitness of a country is a measure of the complexity of the country's productive structure (Hidalgo & Hausmann, 2009; Tacchella et al., 2012). Complex economies are characterised by their diversification and their ability to compete globally with complex (i.e. non-ubiquitous) industrial products. The fitness of a country results in being an effective indicator of competitiveness.

It is based on an intensive measure of diversification and therefore carries complementary information compared to more standard quantifications of economic output, such as the GDP of a country. Economic fitness can also be computed at the sector level.

The interplay between fitness and real GDP per capita at purchasing power parity (GDPpcppp) gives rise to rich dynamics (Cristelli et al., 2015). A quantitative analysis of the microscopic features of country trajectories in the GDP-fitness plane allows for a rigorous, statistically robust description of macroeconomic dynamics. With techniques inspired by the physics of dynamical systems, it is possible to forecast medium term (5 year) GDP growth up to 25% more precisely than the International Monetary Fund (IMF) forecasts (Tacchella et al., 2018).

In addition, the economic complexity framework makes use of the concept of relatedness to forecast the competitiveness of countries at the product level. Relatedness is a quantification of how much two economic activities are related in terms of the endowments and capabilities typically needed for their development. Since it is easier to move between related activities than towards unrelated ones, empirical approaches to quantifying relatedness are currently used to inform government policies and industrial strategies in governments, international organisations and companies (Cader, 2017, Pugliese & Tacchella, 2020).

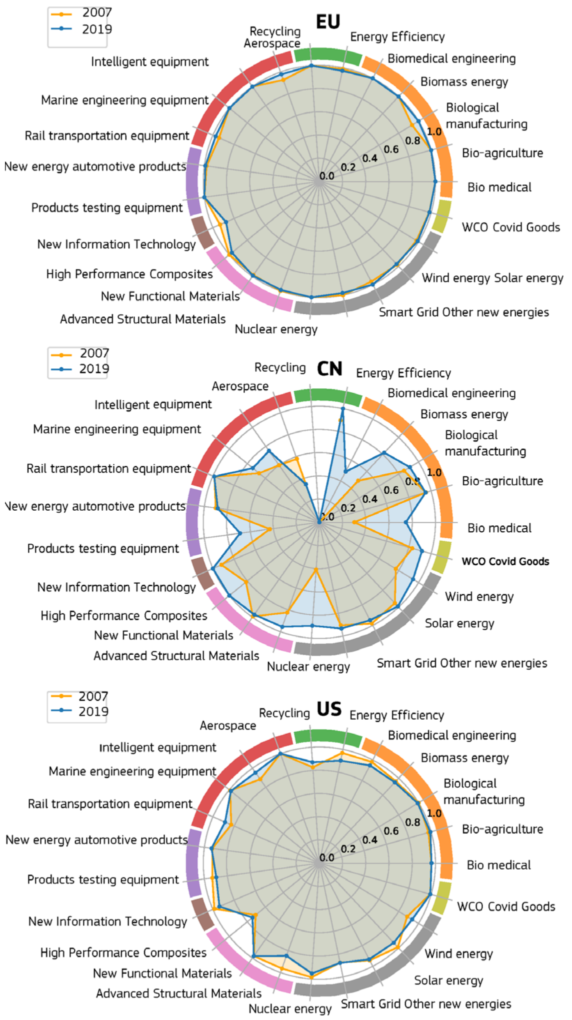
In this report we employ a machine learning approach that is able to create a highly effective representation of the 'relatedness space'. The output of this methodology is the product progression probability (PPP), which represents the probability that a country will become (or remain) a globally competitive exporter of a given product within a 5 year horizon.

5.2 The EU has the highest level of economic fitness in most sectors (except ICT), while China has improved in most sectors, catching up with the US in ICT, materials and energy

In the past decade the EU has consistently held top positions in the economic fitness ranking[26] of all the sectors considered, except ICT (Figure 5.2).

A comparison between 2007 and 2019 shows only minor fluctuations (small improvements in Aerospace, Rail Transportation and Biological Manufacturing), again with the exception of ICT which shows a visible decrease in fitness.

Figure 5.2: Sector Fitness rankings (higher is better)



Source: Eurostat and JRC computations

China has systematically improved its ranking in all priority sectors[27] with the exception of Recycling and a marginal decrease in Aerospace. The Biomedical, Nuclear Energy and Energy Efficiency sectors have seen the most impressive improvements. In several sectors belonging to the IT, Materials and Energy categories, China has caught up and even surpassed the US.

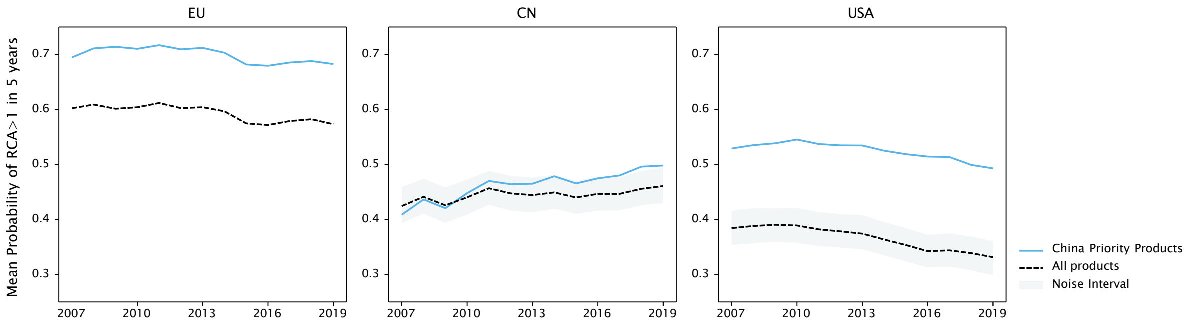
5.3 China is systematically improving its competitiveness in several industries of future strategic relevance, which are traditional strongholds of the EU and the US

The PPP (see Box 1) estimates the probability that a country will be a competitive exporter (revealed comparative advantage (RCA) > 1) of a given product after 5 years. The estimates take into account the current RCA of a certain product as well as the levels of RCA of all related products, which is a proxy for the availability of related capabilities in the country.

Figure 5.3 shows that China's set of priority products coincides with sectors in which the EU and US are particularly strong. This strength of the EU and US stems from the fact that their average PPP for the priority products is significantly higher than the PPP of a randomly selected set of the same number of products (at 99% Confidence Interval (CI)).

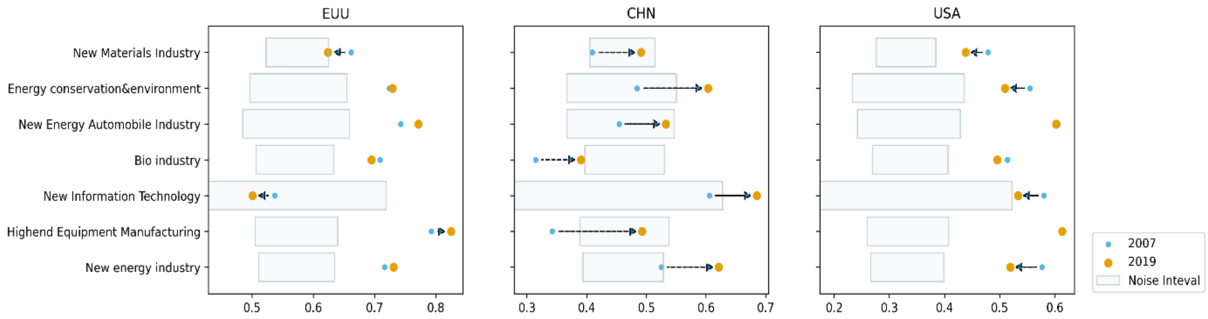
The average PPP of China's priority products was significantly below average in 2007 (99% CI), which suggests that the selected sectors and products were targeting areas where China was trailing global competitiveness.

Figure 5.3: PPP of EU, CN, US in selected sectors versus average products



Source: JRC computations based on COMTRADE

Figure 5.4: Sector breakdown – PPP change 2007-2019 (dots) vs. random selections of products in 2019 (shaded area). Arrows mark most significant changes



Source: JRC computations based on COMTRADE data

Figure 5.4 shows a breakdown of PPP in seven categories. The EU has improved in the New energy automobile industry and high-end equipment manufacturing but has lost ground in the New materials industry and even more so in New information technology. The US has seen a consistent decrease of PPP in all the sectors considered, with the exception of New energy automobiles. China has systematically and significantly improved its PPP across all sectors, some of which are now significantly above the country's average (New information technology, New energy, Energy conservation and environment).

5.4 The EU, China and the US are heterogeneous in their product competitiveness across high complexity sectors

In this section, the PPP of the EU, China and the US is broken down to the product level, for a selected list of products from five categories of the priority sectors (COVID-19 goods, New energy Automobile industry, Wind energy, New functional materials and Rail transportation equipment) and two additional sectors: Consumer electronics and Industry 4.0. The PPP values indicate the expected probability that the economy will be a competitive exporter of each product by 2026.

From these examples, the main emerging trend is that the three economies rarely manage to be competitive across the full spectrum of the sectors, thus highlighting the interdependence and complementarity of the productive systems.

In Wind energy the EU is competitive in all three selected components, but the US and China lack competitiveness in High-voltage distribution panels and Meteorological surveying equipment.

In New energy automotive the EU lacks competitiveness in Lithium-ion cells, while the US does not show good prospects in low-power AC Electric motors, which are used in hybrid vehicles.

For COVID-19-related goods, only China is expected to be competitive in Protective goggles, but at the same time there is a low probability of it becoming competitive in Artificial respirators, where the EU and, to an even greater extent, the US are strong. None of the three appears to be well placed in the category of surgical gloves, but the EU and China show a clear edge over the US.

China leads the group in Consumer electronics, with the EU and the US showing good prospects only in Smartphones. For Laptops, China's PPP is almost twice that of the US and three times that of the EU. The gap is much larger for Printers.

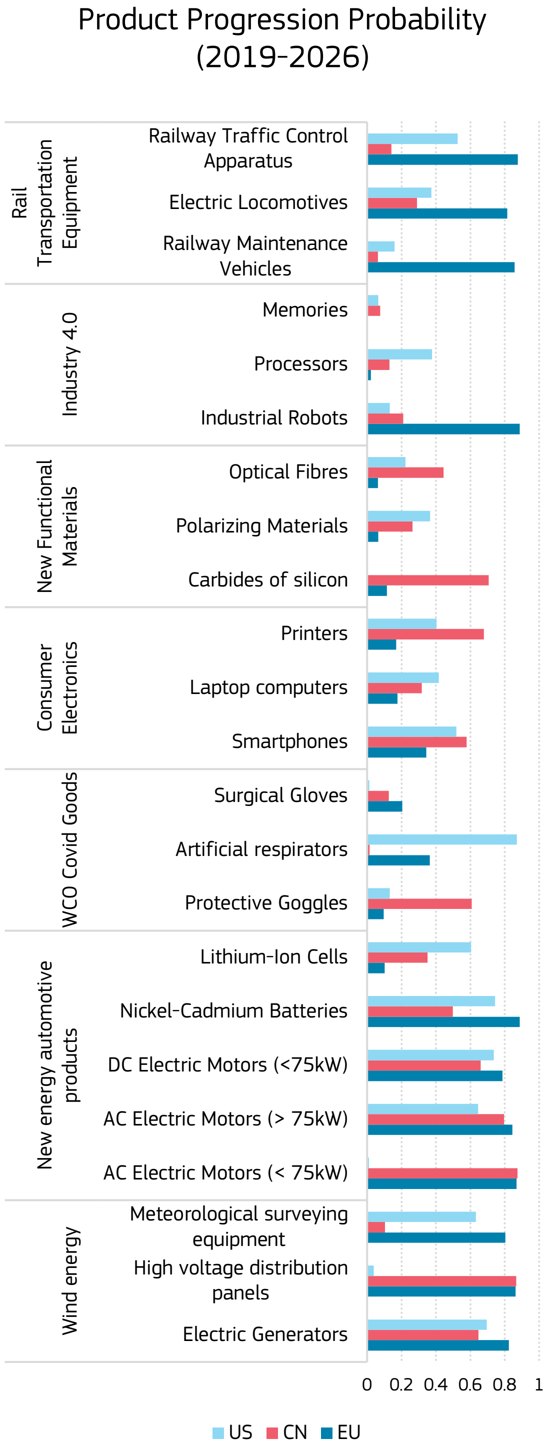
In New functional materials the EU has generally worse prospects than the US and China. Interestingly, and again stressing the complementarity of the three large economies, the US leads the group in Polarizing materials but not in the technologically-related Optical fibres.

Industry 4.0 is characterised by a strong heterogeneity, with the EU in the lead for Industrial robots, but with low expected competitiveness in some components, such as Processors (where the US leads the group by a significant margin) and Memories.

The EU performs better than the US and China in Rail transportation equipment. The US has good prospects in Traffic control equipment and locomotives, but not in Railway maintenance vehicles.

This heterogeneity reinforces the message that none of the three large economies considered in this section is generally able to be competitive in all the components of a sector (Industry 4.0 is perhaps the clearest example), and certainly not across the whole range of high complexity sectors addressed. GVCs, therefore, are expected to continue to play a crucial role in the development of advanced economies.

Figure 5.5: PPP at the product level on selected products



Source: Eurostat and JRC calculations

TECHNOLOGY AND INNOVATION – KEY FINDINGS

China's research and innovation relies on R&D spending, high-tech manufacturing, a steady increase in patenting, high quality research and technological applications, while downsides can be found in a productivity slowdown and the inferior quality of domestic patents

China's R&D spending is highly concentrated in a few high-tech manufacturing and knowledge-intensive services companies, with top innovators specialising in ICT and, more recently, in semiconductors and optics. ICT producers and services sectors account for half of the total R&D investments in China. These investments are rather concentrated, with around 10 companies accounting for 30% of the total R&D of Chinese companies. While this is a key strength, it could also become an important source of vulnerability. A significant upgrading of the ICT manufacturing sector is taking place and there is a clear shift away from low-tech sectors. Semiconductors, optics and audio-visual technology are the fields that have seen the biggest growth both in terms of the total number of patents and of increases in the specialisation index.

China has overtaken the EU in the share of the top 1% most cited publications. The quality of China's publications is steadily growing. Measuring its share of the top 1% most cited papers, China overtook the EU in 2016, and by 2020 it had almost caught up with the US, whose share of the top 1% most cited papers has been falling for the last five years. The most impressive growth in China's specialisation is in the field of molecular biology and genetics, with very significant growth in the number of papers. China is reaching a level of specialisation that is almost level with the US, which is the mostly specialised economy in this field.

China hosts 26% of all economic agents active in artificial intelligence (AI) in the world, and has a comparative advantage in fields such as computer vision (CV), machine learning (ML) and connected and automated vehicles (CAV). China hosts a flourishing AI industry, with 24% of all AI firms worldwide, and has more than one thousand research institutions active in AI (49% of the world total). Almost 50 governmental institutions are intensively promoting the AI economic segment (66%). The Chinese government has designed a multifaceted strategy intended to make China the world's leading AI ecosystem by 2030. The strategy is putting in place several initiatives, such as the Next Generation AI Development Plan, MIC2025 for smart manufacturing and the Robotics Industry Development Plan (2016-2020). These are supported by a wealth of funding, both public and private.

China has experienced a slowdown in productivity growth since 2010 despite high spending on R&D, and its export-led growth is limited by the large size of its domestic market. From a sectoral perspective, the decline in China's labour productivity growth since 2010 seems to be mainly driven by services and to a lesser degree by industry. Despite a continuous rise in R&D spending (as a share of GDP), growth in total factor productivity (TFP) slowed during the 2010s. The export share decreased to 20% from its peak of 36% in 2006 and thereby provides less room for potential catch-up growth.

CHINA'S RESEARCH AND INNOVATION SYSTEM COMPARED TO THE EU AND US

6.1 Expenditures in R&D continue to rise, but China may still not reach its politically set target

Despite the recent tendency to remove explicit references to the Made in China (MIC) 2025 strategy from the official press, speeches, and papers, the strategy continues to play a central role in China's efforts to become the dominant supplier and leading R&D powerhouse in 10 strategic 21st century technologic and economic sectors (Shroff 2020). In 2016 China caught up the EU in terms of gross expenditure on R&D (GERD) intensity. However, it appears China has not achieved its own medium-to-long-term-plan target of R&D expenditure reaching 2.5% of its GDP by 2020 (Figure 6.1).

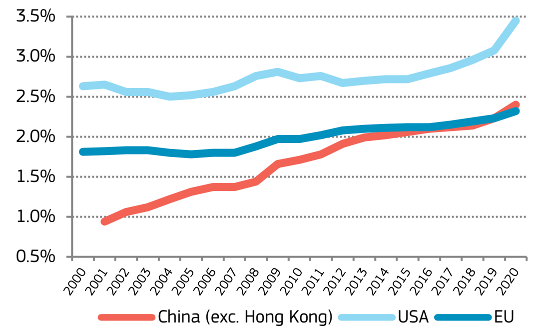
However, missing the target 'should not be perceived as a failure, as China has been increasing its R&D expenditure over the past several decades at a rate higher than its GDP growth' (Cao; Normile, 2020).

6.2 Business expenditure on R&D has outpaced that of the EU, and the gap in high and medium technology manufacturing sectors has almost been closed

According to the 2021 European Innovation Scoreboard, business expenditure on R&D (BERD) is one of the relative strengths of China's R&I performance (EC 2021).

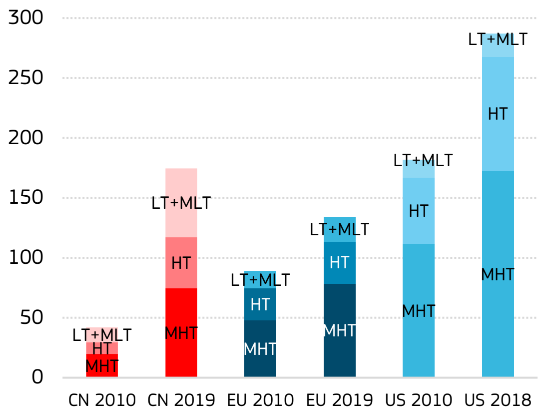
Based on Chinese official government statistics[28], in 2018 Chinese manufacturing BERD increased to EUR 160 billion, which was EUR 33 billion more than in the EU. The gap in BERD in the higher technology intensity manufacturing sectors (HT and MHT), which was rather significant in 2010, was not only closed by 2018, but China overtook EU spending by EUR 1.6 billion. In 2018, the EU invested around EUR 3.3 billion more than China in the MHT sectors but EUR 5 billion less in the two HT sectors (Figure 6.2).

Figure 6.1: GERD intensity (%) - EU, China, US



Source: JRC elaboration, data: Eurostat (EU), China's Statistical Yearbook, OECD (US)

Figure 6.2: Manufacturing BERD in various technology intensity sectors in China and the EU



Source: JRC elaboration, data: Eurostat, China Statistical Yearbook of S&T, National Science Foundation

6.3 Chinese R&D expenditures are still highly concentrated in a limited number of ICT-related, and a few lower R&D intensity companies

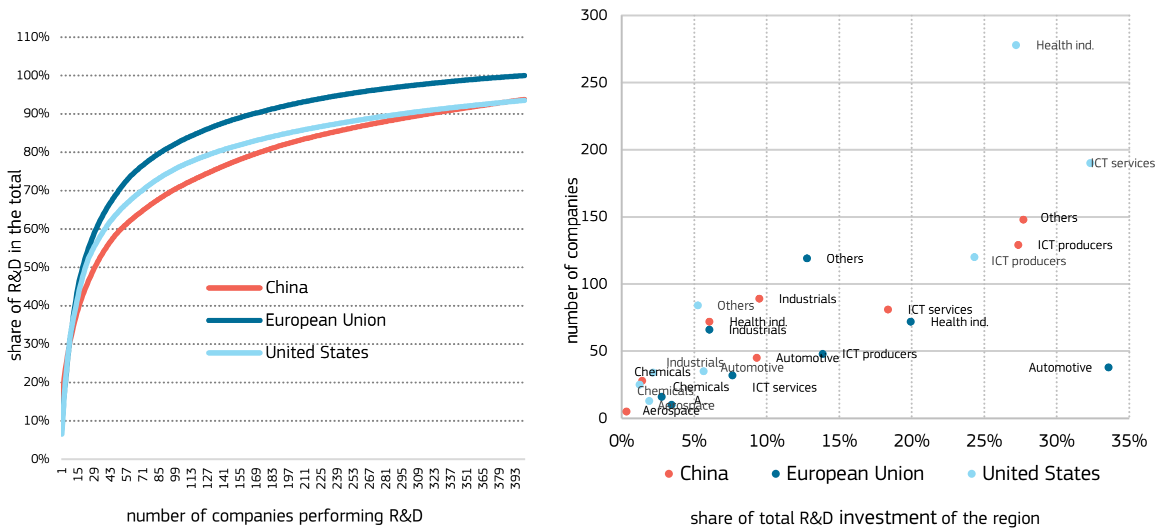
In both China and its main competitors (the EU and the US) R&D investments are remarkably concentrated in a handful of high-tech manufacturing and knowledge-intensive services.

The industrial sectors receiving the highest levels of R&D are usually ICT, automotive and health industries (Figure 6.3).

Apart from these similarities there are also three important specificities for China. First, the concentration of the R&D performed by Chinese firms is somewhat lower than in the EU (the highest) or the US, but still significantly high (Figure 6.3, Left). Second, ICT producers and services sectors account for half of total R&D investments in the country and are rather concentrated, with around 10 companies accounting for 30% of the total R&D of top Chinese R&D investors[29]. While this is a key strength, it could also become an important source of vulnerability. Finally, the 'other' category has a relatively higher share. This category typically includes low R&D intensity companies, particularly in construction and materials, where 30 companies account for 12% of the total R&D of the Chinese top investors.[30]

R&D in the EU is particularly focused on the automotive sector, which accounts for 35% of total R&D. Eight automotive companies account for 30% of total EU R&D, and another 34 for the remaining 5%). Apart from being a clear strength and creating great opportunities in the context of new electric vehicles, these figures also point to an important vulnerability, both directly and through its natural spill-overs towards suppliers of the sector.

Figure 6.3: Left: Concentration of R&D in China, the EU and the US; Right: 2020 R&D Scoreboard investors in China, the EU and the US according to investment share, number of companies and industrial sector



Source: JRC elaboration based on R&D Industrial Scoreboard 2021

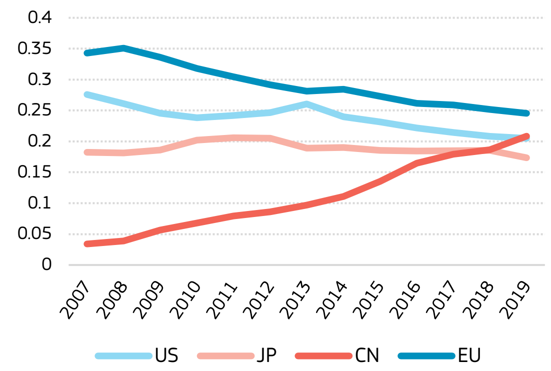
Although the EU has the highest concentration of the number of companies investing in R&D, sector-wise it seems to be the least concentrated, which is shown by the number of industries with positive and/or higher shares (Figure 6.3, Right). The R&D performance in the US takes place in practice in two sectors: ICT and healthcare (equipment and pharmaceuticals), which include high-tech and knowledge-intensive sectors. This means that the US probably has the best R&D mix of the three major competing economies (Figure 6.3, Right).

From 2016 to 2021 it can be observed that China focused more on ICT, especially on manufacturing (ICT producers) and that there was a clear shift away from low-tech, shown by the changes in the 'others' category (Figure 6.4). A significant upgrading of the ICT manufacturing sector is took place. In the EU and US there appears to be no significant changes in terms of the sectoral concentration of R&D performance.

China's patenting activity is growing rapidly and steadily, at the expense of its main competitors[31]. Its output of patents targeting international markets continued to grow between 2014-2017. It has almost caught up with Japan and has rapidly reduced the gaps with the EU and the US. However, the gap between the EU and China is still significant, at around 10% (Figure 6.5).

Since 2019 China has been the top filer of Patent Cooperation Treaty (PCT) international patent applications. However, less stringent utility models, rather than invention patents, still dominate the applications filed and the patents granted in China. As a result, patent applications filed domestically by companies and individuals resident in China also dramatically increased[32].

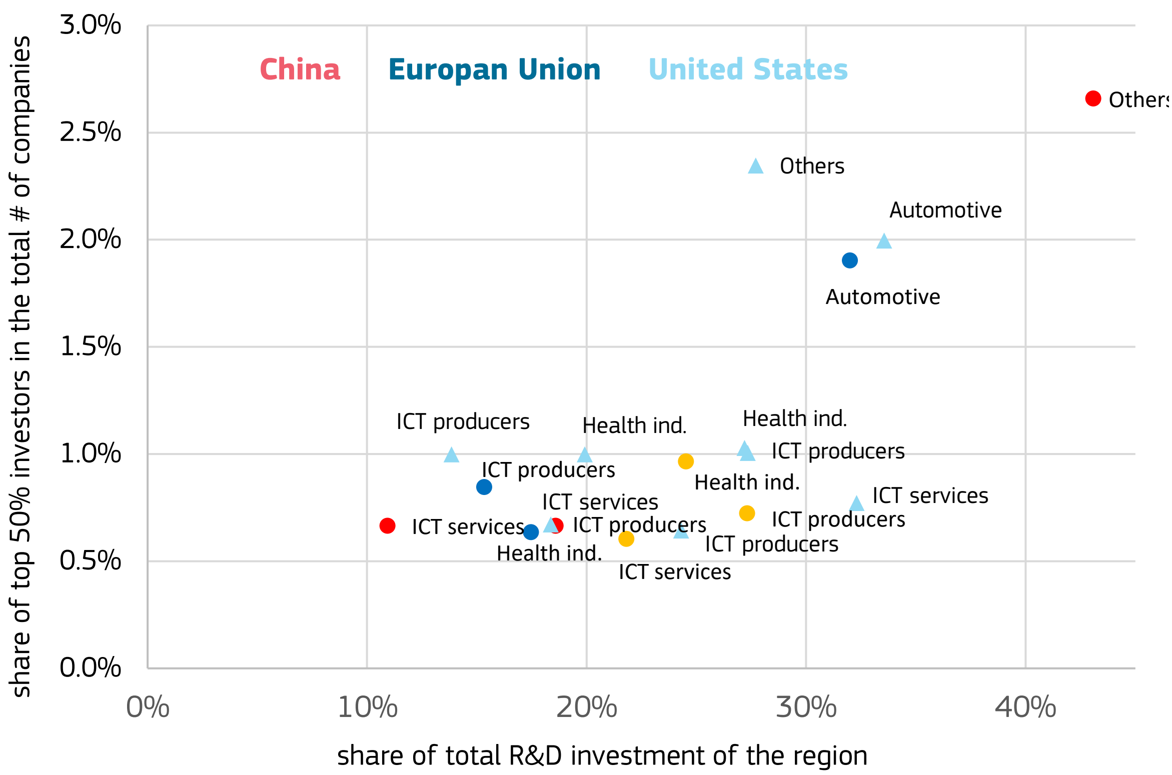
Figure 6.5: World shares in transnational patents filings (EPO+PCT, %)



Source: EPO-PATSTAT; Fraunhofer ISI compilation Last update 17/05/2021

PCT international patent applications originating from China have rapidly increased in recent years, with China surpassing the US and Japan in 2019 to become the top filer of PCT international applications. In 2018 approximately 1.54 million invention patent applications, 2.07 million utility model applications, and 0.70 million design patent applications were filed in China (WIPO, 2017). The numbers

Figure 6.4: Concentration of R&D in the main sectors in China, the EU and the US between 2015 and 2020 (triangles: 2020, dots: 2015)

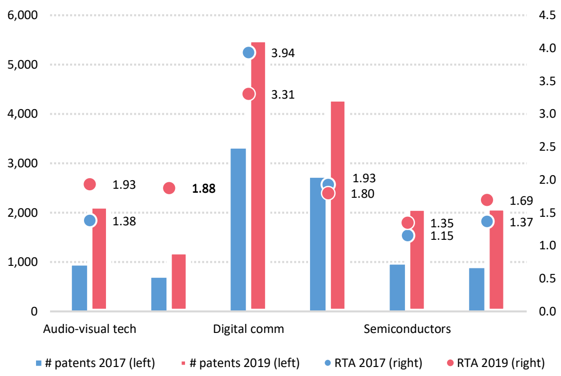


Source: JRC elaboration based on R&D Industrial Scoreboard 2015 and 2021 of utility model and invention patent applications rose significantly from 2014 to 18, with the former surpassing the latter. The share of Chinese invention patent applications filed by residents has also risen noticeably from 50% in 2004 to 90% in 2018. This may reflect a generally positive shift from imported knowledge to a better diffusion of technological knowledge within China, but it may be policy driven, with incentivised patents filed by Chinese residents.

6.4 China specialises mostly in ICT and, more recently, in semiconductors and optics

China's top innovators specialise in relatively few technology fields that are centred on a number of ICT-related technologies (EC, 2019). China has been specialising more than the EU and the US in high technology fields such as ICT, semiconductors, and optics.

Figure 6.6: RTA (index, right axis) and number of patents (left axis) in technology fields in which China specialises most



Source: JRC elaboration – fractional patent count, PATSTAT data

Semiconductors, optics and audio-visual technology have seen the largest increase both in the total number of patents and degree of specialisation (Figure 6.6). The absolute value of RTA[33] in semiconductors was still not very high in 2019 (1.35 up from 1.15 in 2017).

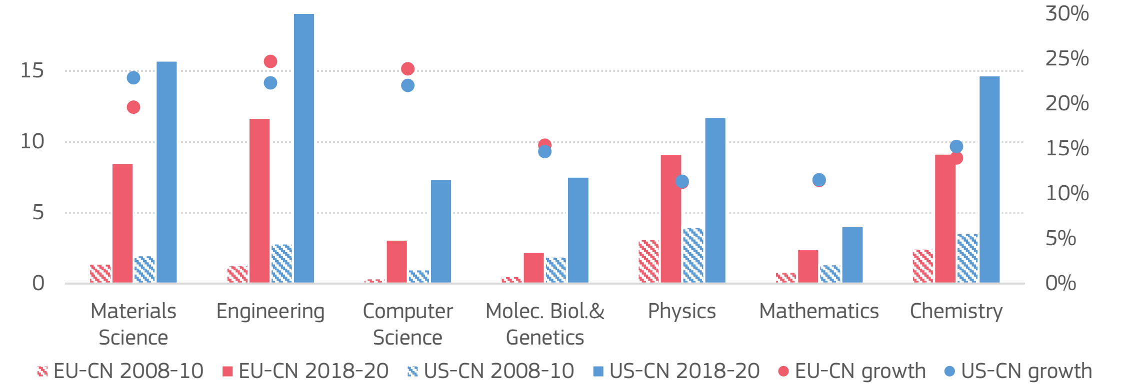
In the six technology fields mentioned above the EU specialises the least in terms of RTA, compared to China or the US. However, fields in which the EU has been specialising the most usually have the fewest Chinese patent applications (Figure 6.7). These mostly are organic fine chemistry, transport, mechanical elements, micro structural and nanotechnology[34].

6.5 China progresses in quantum computing and the EU advances in quantum communications

While the US maintains its lead in quantum computing through universities, technological giants, and dedicated start-ups, China has generated state of the art advances. Chinese patent filings are on the increase, both in absolute terms and relative to other countries (Figure 6.8). In 2019, Google announced 'quantum supremacy', demonstrating for the first time that a purposely contrived computational task can be performed exponentially faster on their 53-qubit superconducting quantum processor than on classical computers (Arute et al., 2019) A Chinese team developed a programmable superconducting quantum processor composed of 66 qubits, which made it possible to establish a computational advantage compared to non-quantum approaches (Wu et al., 2021). A second Chinese team developed a specialised photonic quantum computer with a 10^{24} speed-up in Gaussian boson sampling computational time compared to classical algorithms (Zhong et al., 2021).

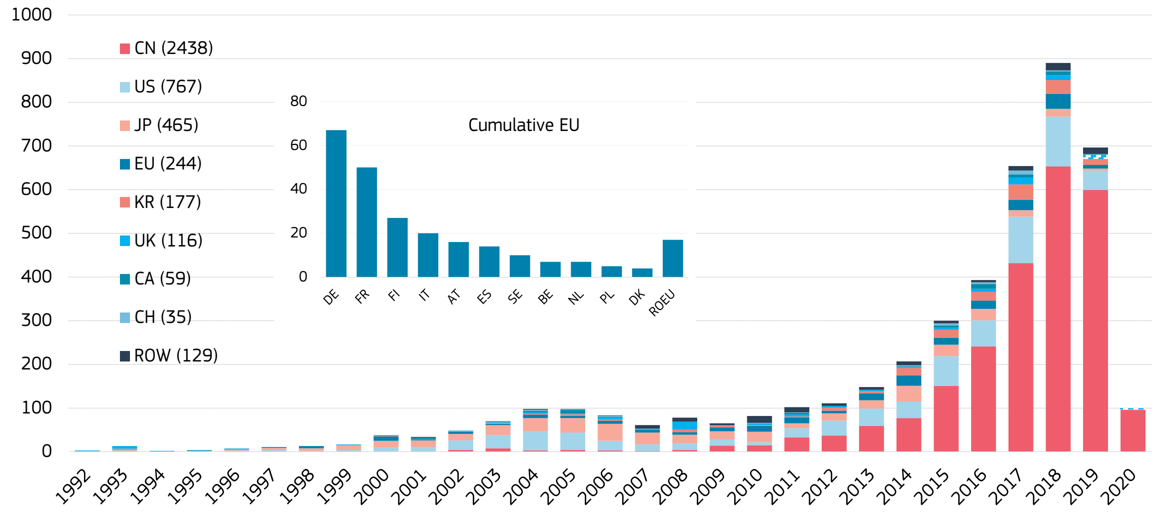
China files by far the highest number of patents in quantum communications technology, among which quantum key distribution has the lion's share (Figure 6.9). This leading position results, at least in part, from a relative lack of interest in this area from China's main competitors. However, public investment in quantum communications also seems to be on the rise now in the western world. In 2021, the US proposed to double spending on quantum information sciences to USD 860 million within two years (Reuters, 2020a), targeting USD 25 million for the Department of Energy to support early-stage research for a quantum internet (USA Budget, 2020). In the EU, quantum key distribution (QKD) local testbeds are receiving tens of millions of euro in funding (the OpenQKD project), while a policy initiative for a much larger EU-wide quantum communications infrastructure[35] is now gathering pace[36].

Figure 6.7: Chinese international co-publications with the EU and the US, (left) and their growth rates (right) by field of science relevant for the Chinese RSA, thousands of papers, %



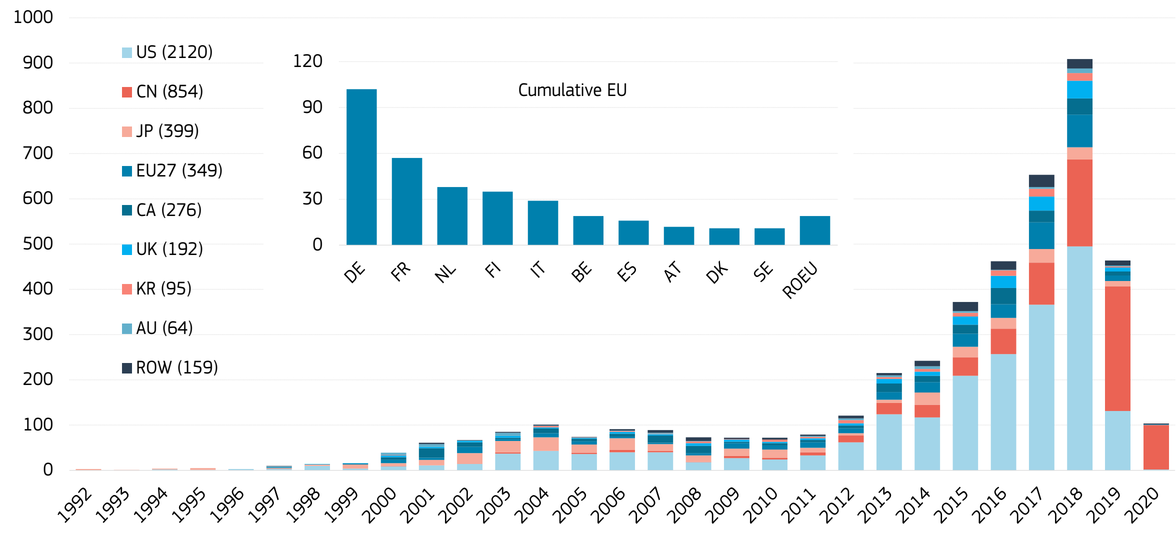
Source: JRC elaboration based on INCITES (Web of Science) data

Figure 6.8: Patent applications related to quantum computing



Note: Data for 2019 and 2020 are provisional, due to an 18-months confidentiality period available to applicants[37].
Source: JRC analysis, based on the European Patent Office Global Patent Index database (4,512 patent families).

Figure 6.9: Patent applications related to quantum communications



Note: Data for 2019 and 2020 are provisional, due to an 18-months confidentiality period available to applicants[38].
Source: JRC analysis, based on the European Patent Office Global Patent Index database (4,440 patent families)

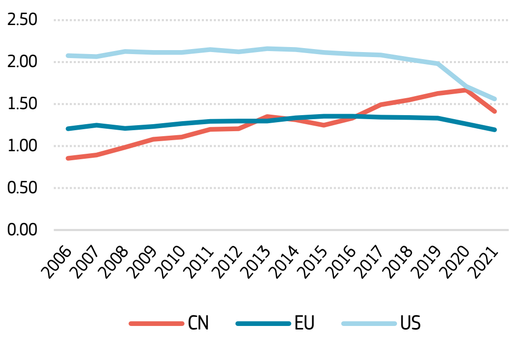
6.6 China has overtaken the EU in the share of top 1% most cited publications, and is closing the gap in patenting where it still lags significantly behind the EU

China's scientific output is increasing steadily. The quality of China's publications is improving strongly. This is apparent from the developments at the pinnacle of scientific excellence measured by the share of the top 1% most cited papers. In this category, China overtook the EU in 2016 (Figure 6.10), and by 2020 it had approached the performance of US authors, whose share of the top 1% most cited papers has been falling for the last eight years. Contrary to China's performance over the past decade, the EU's share seems to be relatively stable during the same period, varying between 1.27% and 1.36%, around its decennial mean of 1.32%.

6.7 China is increasingly specialising in molecular biology & genetics, computer science and engineering

With very few exceptions[39], China has quadrupled its number of publications in each of the 22 scientific fields considered by Web of Science (InCites) data over the last decade. In some fields the increase is even seven- or eightfold.

Figure 6.10: Output in top 1% highly cited publications, %



Source: INCITES (Web of Science)

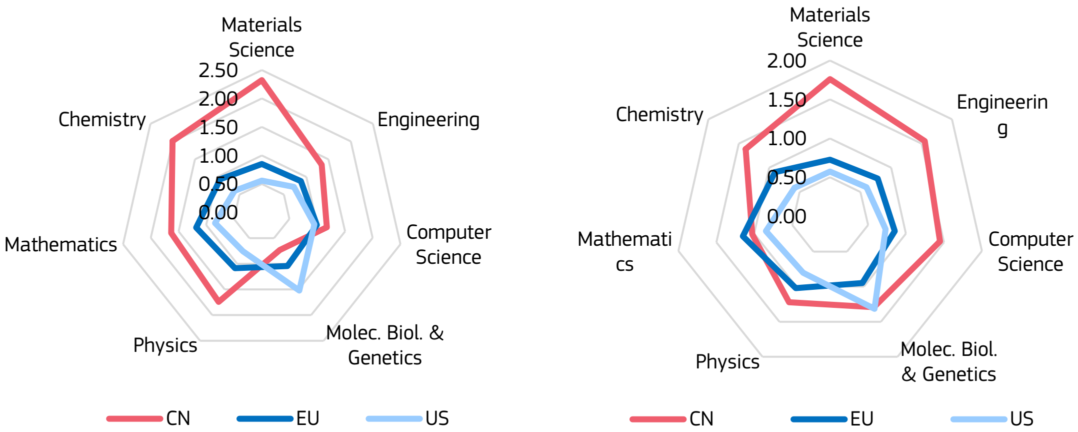
In science and technology fields such as chemistry or molecular biology & genetics China is responsible for at least two thirds of the world increase in total publications, with highest increase in molecular biology (80%). More than half (55%) of the world increase in publications in high-tech industry-related fields such as computer science or engineering, also comes from China.

The most impressive growth in China's specialisation is in the field of molecular biology & genetics with high growth in the number of publications, and reaching a specialisation level almost equal to the US, which holds the highest Revealed Scientific Advantage (RSA)[40] in this field (Figure 6.11). Interestingly, China seems to be turning away from physics, mathematics, chemistry and material sciences – fields with still high, but rapidly decreasing specialisation from the Chinese perspective.

Chinese publications in the fields with the highest RSA show the biggest increases in quality over the last ten years. This is shown by the developments in the share of the top 1% most cited publications (Figure 6.12). Decennial changes in the regional shares of the top 1% most cited publications in the scientific fields in which China specialises the most show that China is gaining ground at the expense of the EU and the US in all relevant fields, even in those where it has reduced its specialisation, such as mathematics, physics, chemistry and material sciences.

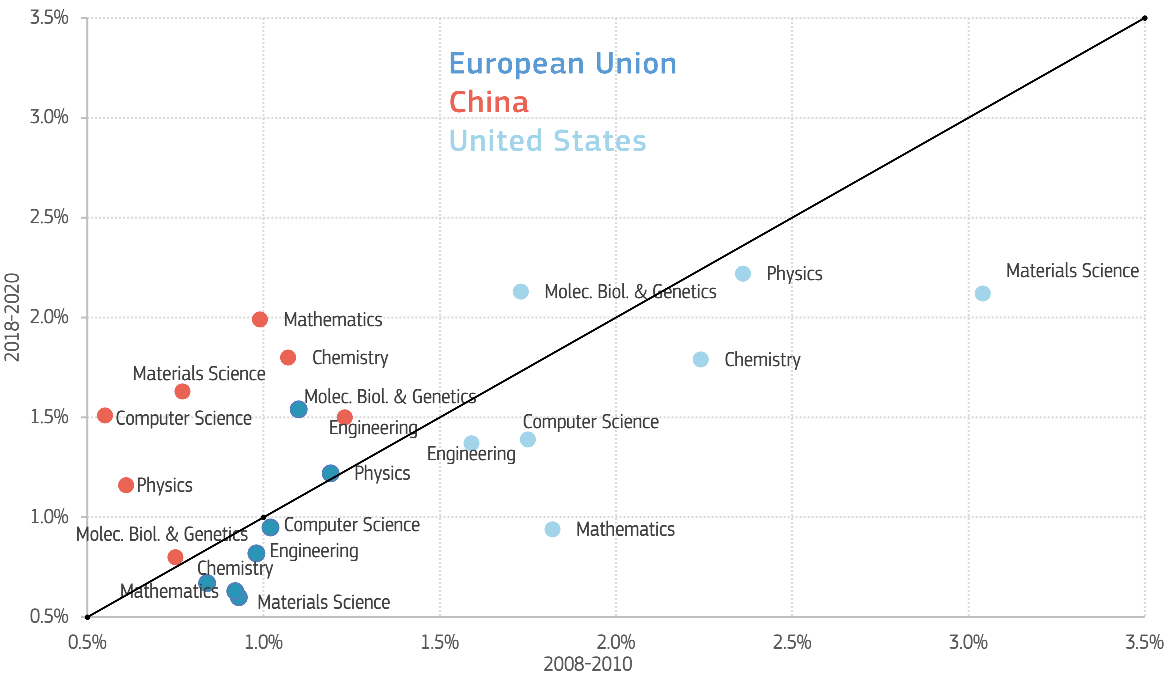
China is becoming the world leader in education technology (EdTech), investing twice as much as the US since 2010 and increasing the number of EdTech users every year since 2016[41]. China is expected to surpass the US in EdTech soon. Both countries host eight unicorns in a shortlist of 18. The capital flow into EdTech in China has been double that of the US since 2010 (USD 19.8 billion in China vs. USD 9 billion USD). The online education market was valued at USD 37 billion in 2019 and was expected to reach USD 56 billion in 2020, with further growth estimated at 20% in the coming years. China's online learners and users of training platforms reached 232 million in June 2019, more than half of whom were learning via mobile devices.

Figure 6.11: Revealed Scientific Advantage (RSA, index): 2007-2009 (left); 2017-2019 (right)



Source: INCITES (Web of Science) data

Figure 6.12: Decennial changes in the shares of the main competitors in top 1% highly cited publications in scientific fields in which China specialises / has specialised the most



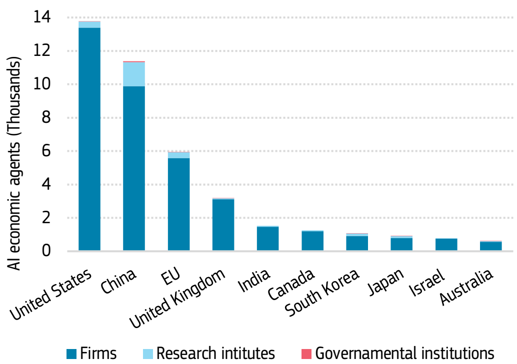
Source: JRC elaboration based on INCITES (Web of Science) data

7.1 China is consolidating its position in the worldwide AI landscape, with strong government support

China is consolidating its position in the AI landscape behind the US, hosting 26% of all AI economic agents worldwide (firms, research institutes (RIs) and government agencies involved in AI) (Figure 7.1). Globally, industry has a very prominent role in the AI ecosystem, as 93% of all identified economic agents active in AI are firms, followed by RIs (7%) and governmental organisations (0.2%). China is not an exception, but presents some particularities.

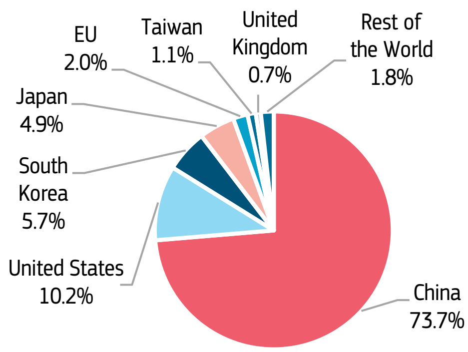
The Chinese AI ecosystem, while hosting a flourishing industry with almost 10,000 AI firms (24% of all AI firms worldwide), also accommodates more than 1,400 RIs (49% of the world's institutions active in AI) and nearly 50 governmental institutions (66% of the world total)[42]. China also has a widespread ecosystem of SOEs intensively promoting the AI economic segment. These companies, mostly operating in the electric state grid, represent 1.4% of all AI firms and are involved in 9.6% of all AI-related Chinese patent applications.

Figure 7.1: Number of economic agents in the AI worldwide ecosystem by agent type. Top 10 geographic areas, 2009-2020



Source: JRC computations based on AI TES Dataset

Figure 7.2: AI patent applications by geographic area (%), 2009-2020



Source: JRC computations based on AI TES Dataset

The Chinese government has designed a multifaceted strategy intended to make China the world's leading AI ecosystem by 2030. The strategy is putting in place several initiatives, such as MIC2025 for smart manufacturing; the Internet Plus action plan, which identified AI and innovation as key priorities; the robotics industry development plan (2016-2020), and the next generation AI development plan, focused on reinforcing science and technology for AI (Arenal et al., 2020).

7.2 AI innovation and research in China

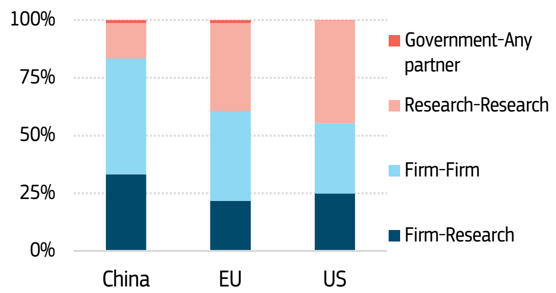
Advancement in theoretical and applied AI does not occur with government funding alone. China has a very innovative industry: 83% of its AI firms filed at least one AI-related patent application between 2009 and 2020 (only 7% in the case of the EU or the US), and Chinese economic agents filed three quarters of AI patent applications worldwide (Figure 7.2).

China's leading position is influenced by the proactive support given by the Chinese government to AI patenting. For instance, the Next Generation AI development plan provided for the establishment of a mechanism for the collaborative application of AI technology patents (Zheng and Liu, 2021). More recently, successive revision processes of the patent examination guidelines in 2020 and 2021[43] face intellectual protection challenges in aspects such as eligibility, inventiveness and sufficient disclosure, and have the goal of increasing the protection of IP for AI in China[44].

The Chinese explosion in AI patenting is not free of controversy due to questions on patent quality, value or business impact capacity[45]. In this regard, the Chinese National Intellectual Property Administration recently announced the end of patent subsidies to be implemented during the 14th Five-Year Plan (2021-2025), in an effort to improve the quality of the country's IP[46].

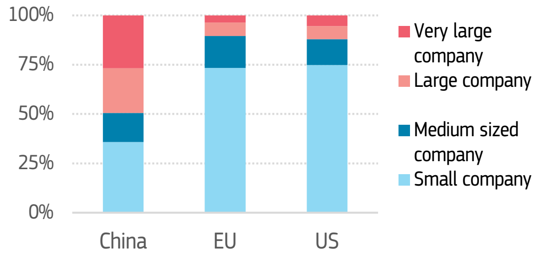
A distinguishing characteristic of China's AI ecosystem is the fruitful collaboration between industry and research: one third of all Chinese collaborations[47] involved firms and RIs (blue bar in Figure 7.3). In 89% of cases, both the firm and the research institution are located in China, showing the tendency of Chinese players to interact within China. Among the top countries in the AI worldwide ecosystem, only South Korea has a higher proportion of firm-research collaboration (38%). In the EU and the US, we observe a higher share of AI-related collaborations between RIs only (38% and 45% of all collaborations, respectively) (pink bar in Figure 7.3).

Figure 7.3: R&D collaboration partnerships (% over total collaborations): China, EU, US, 2009-2020



Source: JRC computations based on AI TES Dataset

Figure 7.4: AI firms by size: China, EU and US, 2009-2018



Source: Adapted from Samoili et al. (2020). JRC computations based on AI TES Dataset

7.3 China's AI industrial fabric relies on manufacturing by well-established large companies

A JRC study analysing the period 2009-2018 shows that China has a consolidated AI industry (Samoili et al., 2020). Three quarters of firms are more than 10 years old, and one in four is older than 20. This is combined with the prevalence of relatively large companies[48] (Figure 7.4) and with a concentration in the manufacturing sector. This result fits with China's traditional strength in the ICT manufacturing sector in value added, employment and BERD (Mas et al., 2020). It also fits with its commercial behaviour: the main trading activity of China in AI is based on the production of hardware, both in the form of whole devices and parts of them, as chips, electronic components and sensors (Righi et al., 2017).

The EU shares several commonalities with the US, with mostly small AI companies (Gregori et al. 2019) although this appears to be a much younger ecosystem, with 62% of the AI firms born in the last decade versus 63% of US firms created more than 10 years ago. The firms located in the EU are more concentrated on the ICT services sector than those in the US or China (Samoili et al. 2020).

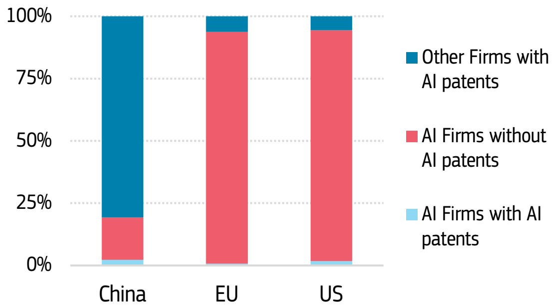
The main AI business type in China is that of firms whose main activity is not AI-related, but who contribute to the technological development of AI with patent applications (Figure 7.5)[49]. Many of these firms are active in the manufacturing sector[50], but also in mining, energy or other sectors[51].

Unlike China, most EU and US companies have their core business in AI but are not active in innovation, which fits with the prevalence of small companies. This concerns a business activity that is mostly focused on providing services to other companies or to individual users.

7.4 China specialises in automation, the internet of everything, machine learning fundamentals and for image processing, as well as computer vision

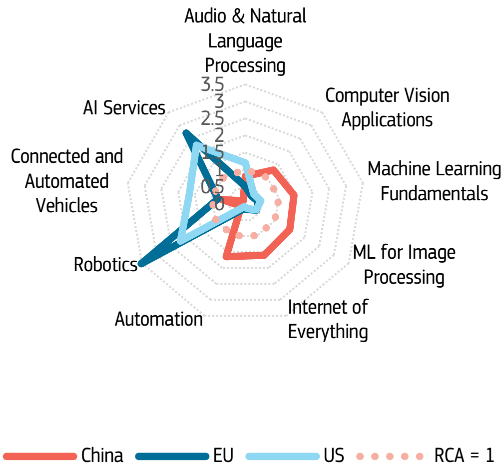
The analysis of areas of specialisation of China's AI activity shows China's RCA in automation, internet of everything (IoE), machine learning (ML) for image processing, ML fundamentals, and computer vision (CV) (Figure 7.6)[52]. China has a higher concentration of activities in these areas than most countries in the world. China also hosts the highest number by far of activities in these thematic areas worldwide (Righi et al., 2021). Several of these specialisation areas are at the core of AI applications in health, where China has a leading position, with a concentration of activities related to devices and diagnostics, in which CV, automation and ML play a central role (Barbas et al., forthcoming). These areas have been promoted by the government, through the next generation AI development plan and a university programme fostering education and teacher training on AI (Samoili et al., 2020).

Figure 7.5: AI firms by AI business type: China, EU, US, 2009-2020



Source: JRC computations based on AI TES Dataset

Figure 7.6: Revealed Comparative Advantage[53] in AI areas: China, EU, US, 2009-2020



Note: The RCA indicator takes values ≥ 0, without an upper limit. In practical terms, most values lie below 5. The value RCA = 1 reflects the benchmark represented by the world average. Values > 1 reveal a comparative advantage.

Source: JRC computations based on AI TES Dataset

The EU's areas of specialisation lie in autonomous robotics, with the world's highest comparative advantage, and AI services (Figure 7.6), where it competes with the US rather than China. The US specialises in these two areas and in connected and automated vehicles, and audio and natural language processing (NLP). The US also has a big share of the world's total number of activities in all AI domains, ranking second after China in the areas led by China, except in CVAs, where Japan occupies the second position and the US is third. In the two areas led by the US (AI services and autonomous robotics), the EU ranks second.

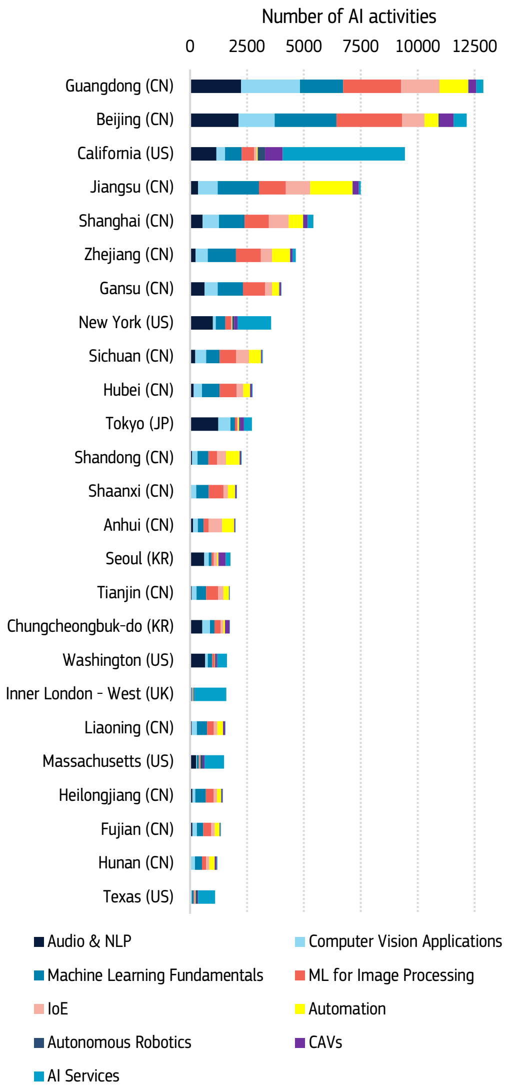
Sixteen Chinese provinces are among the top 25 most active regions worldwide in AI. The strongest ones are Guangdong, Beijing, Jiangsu, Shanghai, Zhejiang and Gansu (Figure 7.7). These six regions account for 35% of the identified worldwide AI activities. The non-Chinese regions in the top 25 are California, New York, Washington, Massachusetts and Texas in the US; Tokyo in Japan; Seoul and Chungcheongbuk-do in South Korea; and Inner London – West in the UK.

In six out of the nine AI thematic areas, a Chinese region ranks first by number of activities: Guangdong ranks first in CVA (18% of worldwide activity), IoE (16%) and Audio & NLP (13%), and ranks second in ML Fundamentals, ML for Image Processing and Automation. Beijing ranks first in ML for image processing (16% of world activity), and ML fundamentals (13%), and ranks second in Audio & NLP, CVA and Connected and automated vehicles. Jiangsu leads in Automation, with 16% of worldwide activity in the area, and ranks second in IoE. The three AI areas not led by a Chinese region are instead led by California: AI Services (17% of worldwide activity), Connected and automated Vehicles (13%) and Autonomous robotics (12%).

Six EU regions are among the top 25 worldwide for some areas of AI. In AI services: Île de France (FR10) and Berlin (DE30); in Autonomous Robotics: Île de France (FR10), Oberbayern (DE21), Centre (FR24), Comunidad de Madrid (ES30), and Liguria (ITC3); in Connected and Automated Vehicles: Västsverige (SE23).

Multiple Chinese provinces are involved in AI. The strongest ones are Beijing, Guangdong, Jiangsu, and Shanghai. Beijing is the world leader in natural language processing (closely followed by California), and ML (the next region reaching 70% of Beijing's level of activity), and also stands out in CV (2nd), and CAVs (3rd). Guangdong is the world leader in CV, and second in CAVs. Jiangsu is the world leader in CAVs, and also very active in ML (2nd) and CV (3rd). Shanghai is second in robotics and automation, with less than 40% of the activity performed by the world leader, California, which also has the leading position in AI services, and is far ahead of the second region, New York (20% of activity).

Figure 7.7: Top 25 worldwide regions by number of AI activities by AI area, 2009-2020



Source: JRC computations based on AI TES Dataset

PRODUCTIVITY IN CHINA

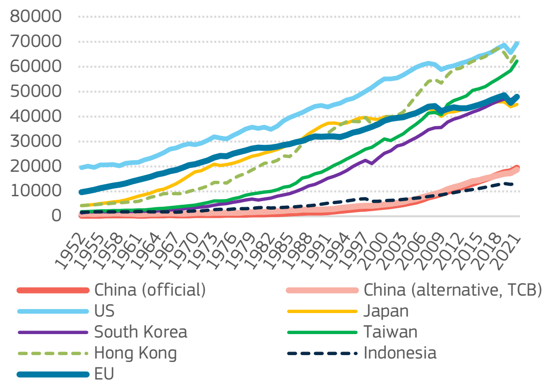
8.1 Despite rapid convergence, China is still far from the frontier

China's level of development is still low compared to advanced economies (Figure 8.1). Currently, its GDP per capita (at 2019 USD PPP) is 26% (official data) or 21% (alternative data[54]) of the US (Figure 8.2). When we compare China's performance with other successful countries that are catching up, we can use as a measure the distance to the concurrent level of the 'frontier', which we assume to be the US. This gives a better idea of the amount of catch-up needed than comparing the constant PPP per capita income level. The constant PPP per capita income of China (official estimate) in 2019 was reached by Japan, Taiwan and South Korea in 1971, 1990 and 1994 respectively. China's distance to the frontier in 2019 (official estimate) was reached by Japan, Taiwan and South Korea in 1957, 1980 and 1987 respectively.

Behind the average national level of development, there are large regional disparities (Figure 8.3). Regional GDP per capita ranges from more than twice the national value to half of it[55]. Putting these numbers into the international context, Beijing and Shanghai's GDP are close to those of several central and eastern European countries (e.g. Hungary, Poland, Slovakia), while GDP per capita of Gansu, the lowest of the Chinese regions, is close to India's.

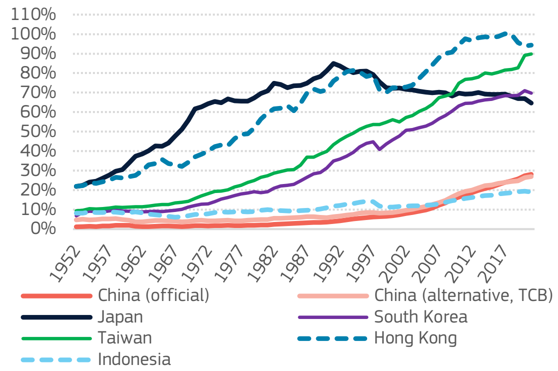
Although the most developed regions have shown high growth in the past 10 years, there is internal convergence in China, as the growth rates of the least developed regions are even higher. Internal convergence can help the whole country to catch-up with other economies. Growth in GDP per capita can be decomposed into the contribution of labour and labour productivity growth. The contribution of labour is the growth in the employment-to-population ratio (Figure 8.4). This has been negative since 2007, which is driven by the ageing of the Chinese population. Consequently, catching-up is driven by labour productivity growth.

Figure 8.1: GDP per capita (2021 USD PPP)



Source: JRC elaboration based on The Conference Board

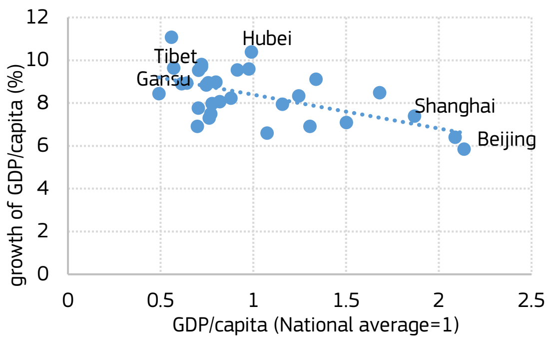
Figure 8.2: GDP per capita, PPP, US=100%



Source: JRC elaboration based on The Conference Board

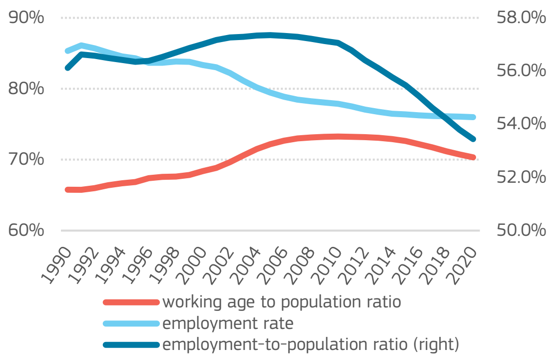
Labour productivity growth can be decomposed further into the contribution from the growth of capital and the growth of total factor productivity (TFP) in a growth-accounting framework. One of the main drivers of TFP growth is innovation. We will follow this logic when we first show the development of labour productivity growth, both at the aggregate and at the sector level. Then the role of state-controlled enterprises is highlighted. For the role of capital in productivity growth, we use an indicator of the return on investment. Finally, we show the development of TFP and how this might be affected by R&D investments and export activity.

Figure 8.3: Regional differences of the level and growth of per capita income (National average=1, 2010-2019 average)



Source: National Bureau of Statistics of China

Figure 8.4: Decomposition of the employment-to-population ratio (%)[56]



Source: The Conference Board and World Bank data

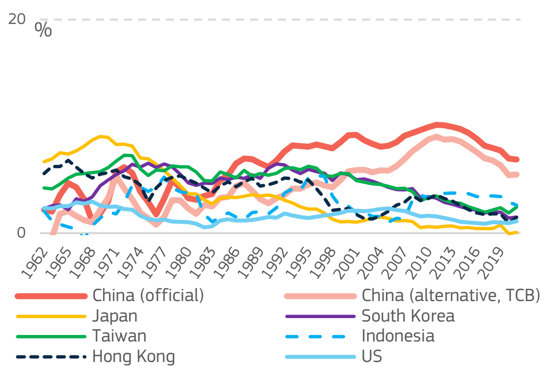
8.2 Labour productivity growth is still high despite a marked slowdown

As the share of employed people in the total population has been decreasing since 2007, the rise in GDP per capita has been driven by labour productivity growth (Figure 8.5). China's labour productivity growth started to slow down after 2010, later than its GDP growth (which started to decelerate after 2007). However, the relatively lower level of labour productivity growth in 2019 was still high compared to that in advanced economies. It is also significantly higher than the labour productivity growth of Indonesia, a country with a similar catching-up and level of development profile. By historical comparison, China's recent productivity growth is higher than or similar to the labour productivity growth of South Korea, Taiwan or Hong Kong when their income levels relative to the US were similar to China's now (late 1970s to early 1980s, or early 1960s in the case of Hong Kong). On the other hand, Japan's productivity growth was spectacular in the 1960s (higher than China's growth now) despite being much closer to the frontier than China. The supporting global economic environment of the 1960s might explain this extraordinary growth.

Looking beyond the aggregate level, sectoral productivity growth is analysed in Figure 8.6. Labour productivity growth in the primary sector (agriculture) increased over time. The secondary sector (industry and construction) saw a sharp decrease in its productivity growth in the 2000s, and recently a minor decrease. In the tertiary sector (all services) there was a significant increase in the 2000s, then a marked slowdown in the 2010s.

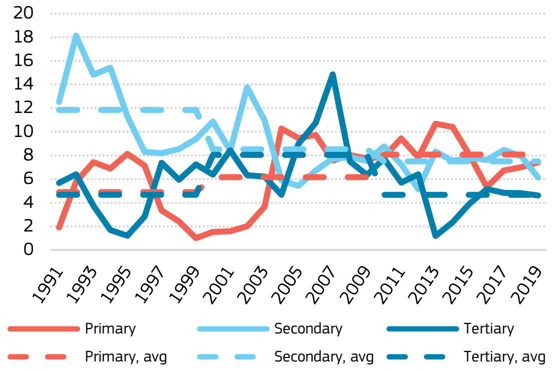
Aggregate productivity growth depends not only on productivity growth within broad sectors but the changing shares of these sectors.

Figure 8.5: Labour productivity growth (10-year moving average of the growth in GDP per employed persons, %)



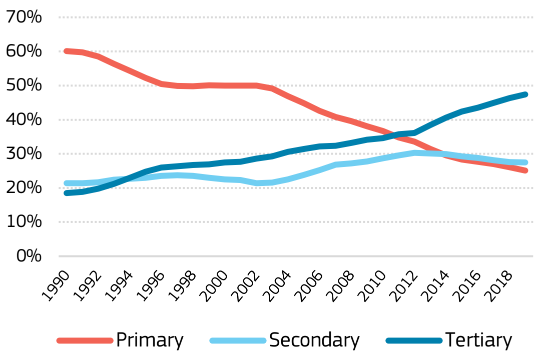
Source: JRC elaboration based on The Conference Board

Figure 8.6: Labour productivity growth in the three broad sectors of the Chinese economy (growth in real value added per employed persons, %)



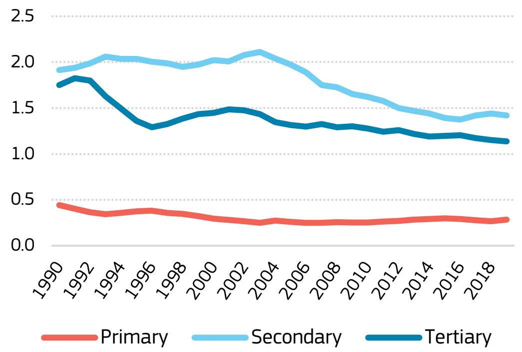
Source: National Bureau of Statistics of China

Figure 8.7: Employment share in broad sectors



Source: National Bureau of Statistics of China

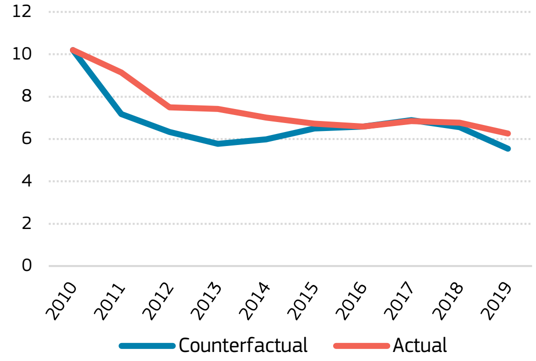
Figure 8.8: Relative productivity level of the three broad sectors (aggregate labour productivity=1)



Source: National Bureau of Statistics of China

Indeed, sectoral shift was dramatic and fast (Figures 8.7 and 8.8). The primary sector's share of employment fell from 50% in 2003

Figure 8.9: Aggregate labour productivity growth, actual and counterfactual without structural change (%)



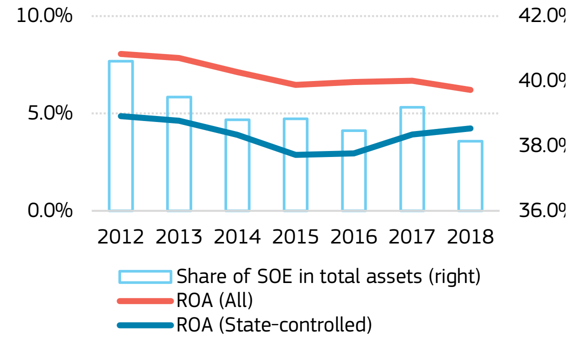
Source: National Bureau of Statistics of China

to 25% in 2019. At the same time, there was a 10 percentage points increase in the share of the secondary sector until 2012, when it started to slightly decrease to just below 30%. In the tertiary sector, there was a huge increase from 30% in 2004 to just below 50% in 2019.

These changes are connected to sectoral productivity. The shift from agriculture is probably motivated by labour-saving technological advancements providing an opportunity to shift labour to more productive sectors. The recent deceleration in service productivity growth is led by the inflow of low-skilled labour from agriculture and partly from industry. The shift in the share of sectoral employment affects aggregate labour productivity growth. On one hand, there is a major shift from low to medium productivity levels (from agriculture to services) and a minor shift from high to medium levels (from industry to services)[57]. On the other hand, the weight of the tertiary sector with low productivity growth has increased.

The overall effect of these changes can be gauged by using a counterfactual calculation where we fix the employment weights of different sectors in the past and compute the aggregate labour productivity growth using these weights (Figure 8.9). The resulting sectoral changes increased labour productivity growth, thus it cannot explain the slowdown of productivity growth since 2010.

Figure 8.10: Return on assets (ROA) and state-controlled firms in the industrial sector (%)



Source: JRC - National Bureau of Statistics of China

8.3 Inefficiencies are present in state-controlled firms and in investments in general

State ownership and control is significant in the Chinese economy. The share of total assets of state-controlled firms is about 40% in the whole industry, although this is gradually decreasing. Based on the return on assets (ROA) indicator, state-controlled firms are less productive or less efficient (Figures 8.10 and 8.11). State ownership is also high in some commercially oriented services (OECD, 2019).

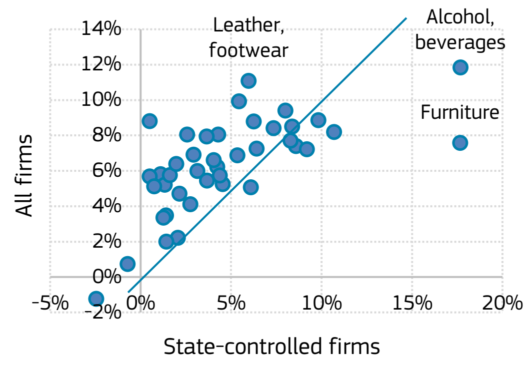
According to the incremental capital-output ratio[58] (ICOR), both aggregate investment (Figure 8.12) and R&D investment (Figure 8.13) generate less and less output per unit of expenditure in China. This is the joint result of a slowdown in GDP growth since 2007, the increase in the investment rate until 2013 (for all investments) and the continuous increase of R&D expenditure as a share of GDP. The ICOR increased similarly for Indonesia, a country with a comparable recent track record of catching up. Similar reasons apply, although the investment rate is lower than in China. Despite ICOR rapidly increased, its level is still lower for China than for advanced economies thanks to the continuing high GDP growth rate.

8.4 Slowdown in productivity growth despite high R&D spending

Like labour productivity growth, total factor productivity (TFP) growth also slowed down during the 2010s. However, based on official GDP estimates, current TFP growth is, in fact, much higher than in any of the advanced economies. Based on alternative GDP estimates, by contrast, TFP growth was very low in particular in the last 5 years when it was massively negative (Figure 8.14). Alternative GDP data suggest a lower GDP growth while the growth in labour and capital are basically the same (with almost zero growth in labour). Besides, the capital share of income is significantly higher than in official data. These factors together lead to a much lower TFP growth than in official estimates, and GDP growth is explained almost fully by the growth in capital. Another explanation for lower GDP growth is to consider a part of capital investments as redundant. In that case, the capital contribution would be lower and TFP growth higher.

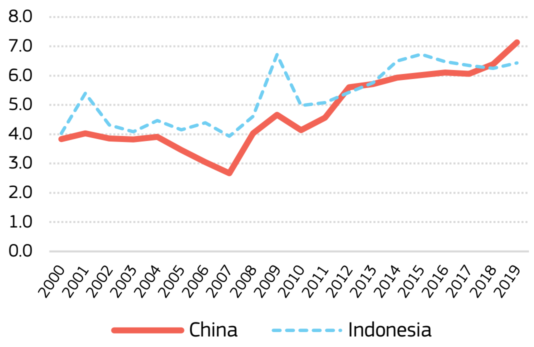
China spends more on R&D (as a % of GDP) than any other country with a similar per capita income level (Figure 8.15). Although there is no apparent correlation between countries' R&D expenditure and TFP growth over recent times, China's R&D effect on productivity growth depends on which data are used. In official data, China's high spending on R&D is coupled with a relatively high TFP growth. With alternative data, despite high R&D expenditure, China experiences negative TFP growth (Figure 8.16)[59]. While R&D expenditure is especially high compared to countries with a similar income level, the number of researchers (per one million inhabitants) is mostly in line with China's level of development (Figure 8.17).

Figure 8.11: Return on assets of all / state-controlled firms in industry subsectors (%)



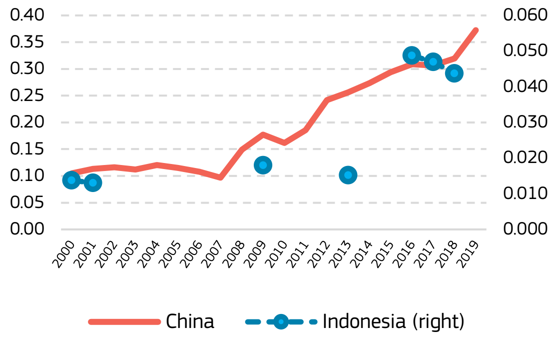
Source: JRC - National Bureau of Statistics of China

Figure 8.12: The incremental capital-output ratio (ICOR) for all investments



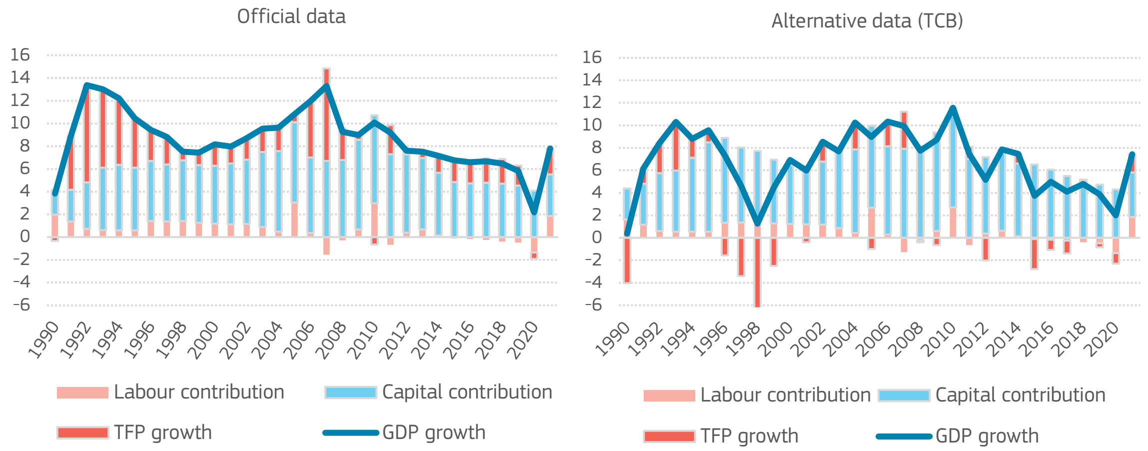
Source: JRC calculation based on World Bank data

Figure 8.13: The incremental capital-output ratio (ICOR) for R&D expenditure



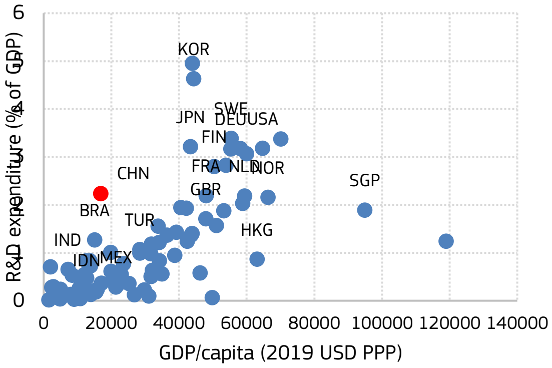
Source: JRC calculation based on World Bank data[60]

Figure 8.14: Decomposition of GDP growth - official (left) alternative (right) data (percentage points)



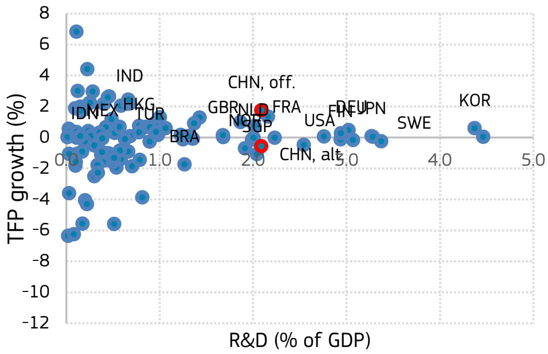
Source: The Conference Board

Figure 8.15: R&D expenditure as a share of GDP (2018)[61] and GDP per capita (2019, PPP)[62]



Source: World Bank and The Conference Board

Figure 8.16: Total factor productivity (TFP) growth and R&D expenditure (% of GDP), average of 2013-2019



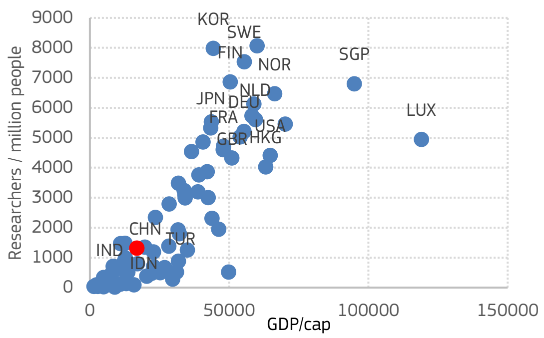
Source: World Bank and The Conference Board

8.5 Exports allow China to catch up less than they did in the past

Despite the link between exports and productivity, global trade now supports Chinese growth less than in the past. Since the global financial crisis, growth in global trade and in Chinese exports has slowed down (Figure 8.18). China's share of world goods exports peaked in 2015 and has stagnated since then. China's share of world exports is much lower in services than goods, and has been stagnating since 2010. Increasing its share of trade in services could support China's economic development, especially since global trade has recently been more dynamic in services than goods (Figure 8.19). Likewise, the large size of the Chinese economy limits further export-led growth. Exports' share of GDP peaked at 36% in 2006, since then it decreased to about 20%, in line with the growth of China's whole economy. Future growth will increase the total size of the economy, thus a further decline of the export share is expected (Figure 8.20).

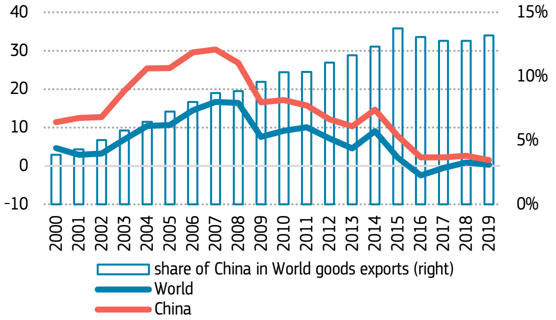
Exporting several complex products tends to be positively related to the productivity and growth of a country. Economic fitness[63] is an indicator for this relationship (Tacchella et al., 2012). China's economic fitness was already quite advanced 10 years ago, and it has improved since then. Currently it is second only to the US (Figure 8.21) when comparing it to EU Member States separately[64].

Figure 8.17: Number of researchers per million people (2018)[65] and GDP per capita (2019, PPP)[66]



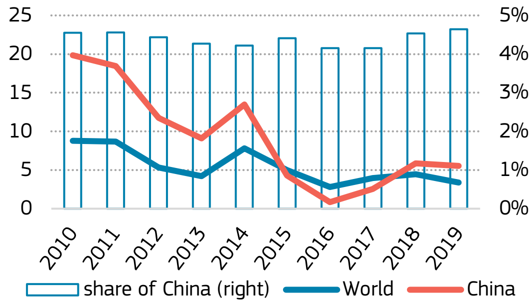
Source: World Bank and The Conference Board

Figure 8.18: China's share and growth in goods export (5-year moving average, %)



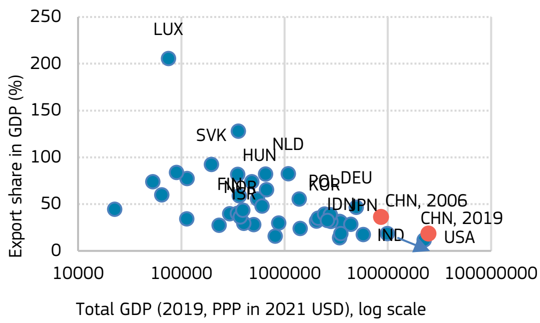
Source: JRC calculation based on WTO data

Figure 8.19: China's share and growth in services exports (5-year moving average, %)



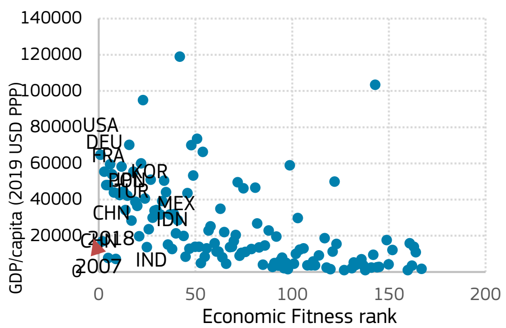
Source: JRC calculation based on WTO data

Figure 8.20: Export share in GDP (%) and size of the economy (Total GDP, 2019, PPP)



Source: OECD and The Conference Board data

Figure 8.21: Economic Fitness rank and GDP per capita (2019, PPP)[67]



Source: JRC calculation based on the methodology of Tacchella et al. (2012).

INVESTMENTS AND CAPITAL MARKETS – KEY FINDINGS

Chinese investments in the EU focus on high-tech and manufacturing, with lower job creation, larger domestically oriented VC funds, but systemically riskier banks

Chinese M&As in the EU grew by 21% from 2013-2016 to 2017-2020, faster than inbound deals from any other strategic partner country. These M&As mostly targeted manufacturing firms. While Chinese M&As accounted for a relatively small share of deals (5% of inward M&A deals in the EU over 2013-2020), the 21% increase was the highest among strategic partner countries (e.g. US, Japan). European firms operating in the manufacturing sector are attracting the largest share of Chinese M&A deals (more than 47%) over 2013-2020.

Chinese acquisitions and exports to the EU in high-tech sectors were higher than in low-tech sectors before the COVID-19 outbreak. Chinese M&A and exports to the EU in low- and high-tech sectors seem closely linked: the reduction in M&A deals in high-tech and low-tech sectors coincides with a slowdown in imports for both groups, starting in 2018. The average growth rate in imports of low-tech products fell from 10% in 2014-2015 to 4% in 2018-2019, while the average growth rate in all imports fell from 13% in 2014-2015 to 7% in 2018-2019. While the number of Chinese M&A deals involving EU firms operating in high-tech sectors was higher than investments in low-tech sectors in the period 2013-2019, EU imports from China in high-tech sectors surpassed imports in low-tech sectors from 2017 onwards.

Technology-oriented Chinese companies prefer radically new technologies not already in their portfolios, compared to European peers engaging in higher shares of coherently diversified M&A deals. Chinese multinational companies (MNCs) with a patent have the highest share (43%) of incoherently diversified technological acquisitions among peers (EU: 31%, US: 35% and Japan: 33%), while technology-oriented EU MNCs have the highest share of coherently diversified acquisitions (60%), compared to China (52%), the US (57%) and Japan (57%).

China's VC market doubled the size of the EU's in 2019 and Chinese VC funds are five times larger than EU counterparts from 2015 to 2020, with about 71% of their capital invested in China. Chinese VC funds are larger than their European and US counterparts, and the gap has not narrowed over time. Their larger size allows Chinese funds to invest higher amounts on average in each portfolio company, while investing in a smaller number of companies. 71% of all capital invested by Chinese funds went to Chinese companies, while 15% went to the US and 1% was invested in the EU. By contrast, EU funds invested a large proportion of their capital in the US (26%), but only 1% in China. The majority of EU funds invest in US businesses and just a small proportion of their investments are in Chinese companies.

China's banking system is the world's largest but ranks first for systemic risk. China ranks first in the risk of its major global financial firms defaulting on their own investments (NY Stern SRISK, 2021). As China's largest banks are government-owned and play a critical role in funding state-owned enterprises and government projects, the systemic risk is highly correlated with government default.

9.1 Chinese M&A deals in the EU grew significantly in the last years

Over the last decade, China improved its position in the ranking of countries investing in the EU, becoming the fourth largest foreign investor after the US, UK and Switzerland (CH) as regards the number of inward M&A FDI deals[68] (Figure 9.1). Between January 2013 and September 2020, there were more than 1,300 deals involving acquirers based in China (CN) or Hong Kong (HK), about 5% of inward brownfield FDI deals.

Focusing on pre-COVID19 years, the yearly average number of Chinese-originated acquisitions was almost 6% higher during the period 2017-2019 compared to the average between 2013 and 2016. Investors from other top partner countries like the US, Switzerland, and Japan (JP) reported smaller increases or even reductions between the same time periods (Figure 9.2).

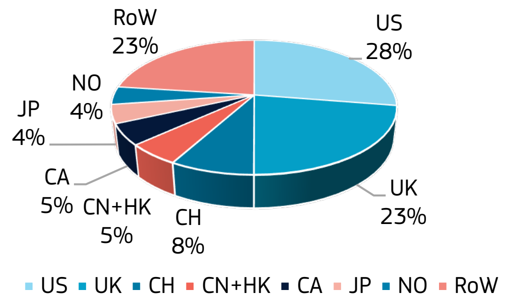
The surge in the number of deals in the period 2017-2019 is mostly due to deals completed in 2017 and 2018. After 2018, there was a sizeable drop in the amount of Chinese investments in the EU (Figure 9.3). This decline was complemented by a reduction in the total amount invested, starting from 2017 onwards.

The combined value of completed Chinese FDI transactions fell to EUR 11.7 billion in 2019, down 33% from EUR 17.4 billion in 2018. This represents the lowest investment level since 2013 (Rhodium, 2020).

The evolution of Chinese FDI in the EU mirrors the sharp drop in the amount of FDI observed at the global level during the COVID-19 pandemic (OECD, 2020a; UNCTAD, 2020). Taking a closer look at January to December 2020, total Chinese FDI deals in the EU were 36% lower than those observed in the same period of 2019 (the corresponding value for all foreign FDI deals was 23% lower). Foreign FDI deals in the EU reached their lowest value in September 2020 due to the pandemic. Nevertheless, the last quarter of 2021 showed a similar trend to 2019, suggesting that a mild recovery phase is in place (Figure 9.4).

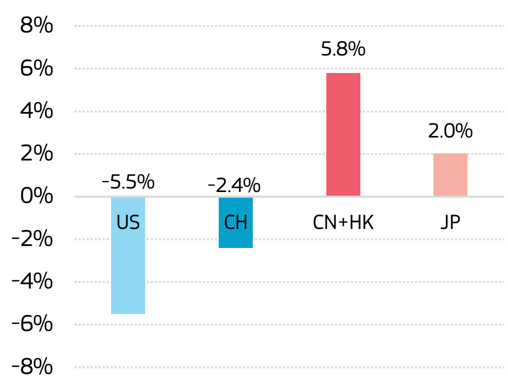
The recovery of M&A activity started in the summer of 2021, reaching pre-COVID-19 levels in the second half of the year.

Figure 9.1: Number of M&A Deals in EU, top investing countries, 2013-2021



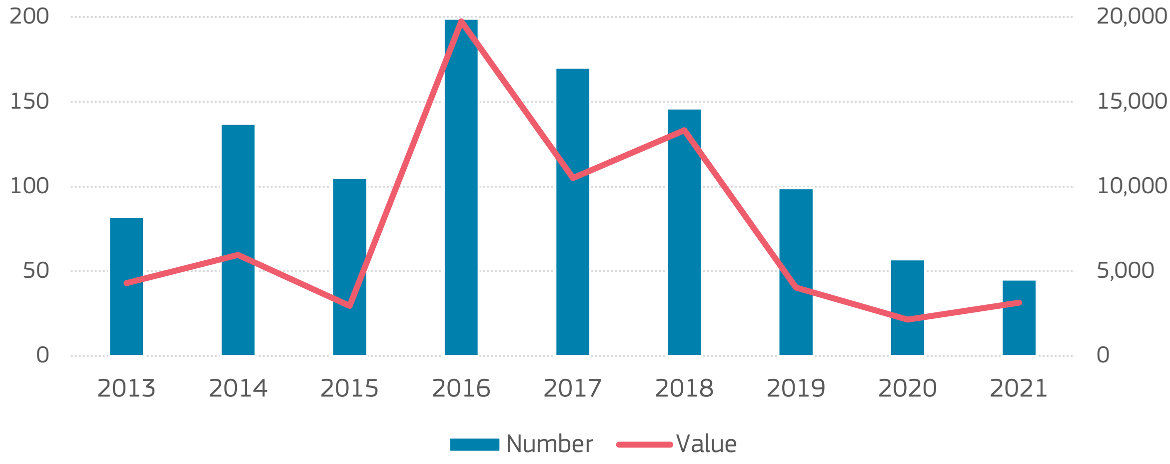
Source: JRC calculations on Bureau van Dijk data (extraction date: May 12, 2022)

Figure 9.2: Growth of M&A Deals in EU, variation in period averages, 2017-2019 to 2013-2016



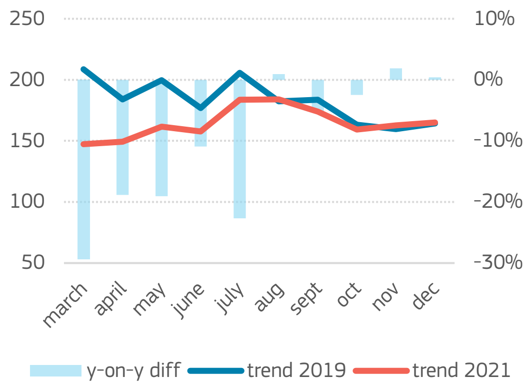
Source: JRC calculations on Bureau van Dijk data (extraction date: May 12, 2022)

Figure 9.3: China and Hong Kong M&A Deals in EU, number of deals and total value, 2013-2021



Note: Information on monetary values is available, on average, for 60% of deals each year. Number of deals on the left axis, monetary value (million EUR) on the right axis.
Source: JRC calculations on Bureau van Dijk data (extraction date: May 12, 2022)

Figure 9.4: Number of FDI deals in EU from the rest of the world, monthly trends and year-on-year difference



Source: JRC calculations on Bureau van Dijk data (extraction date: May 12, 2022)

9.2 Chinese deals in the top EU destinations and sectors confirm a focus on manufacturing

European firms operating in the manufacturing sector are, by far, attracting the largest share of Chinese M&A deals into the EU. Between 2013 and 2021, more than 47% of acquisitions targeted manufacturing firms, 9.3% of acquired firms operate in the information and communication sector, while the retail and finance & insurance sectors account for over 7.7% of deals. Investments in the manufacturing sector, after a peak in 2018, declined in the following years, marking a 70% fall in 2021 with respect to 2017. Starting from 2019, a reduction in Chinese FDI can also be observed in the other top sectors (Figure 9.5).

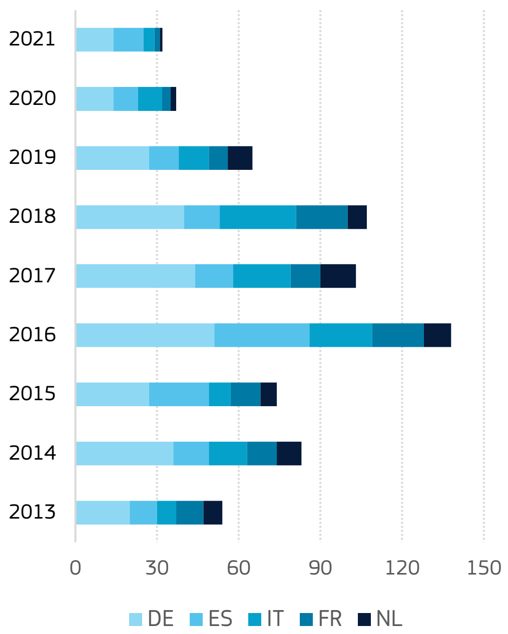
Between 2013 and 2021, the top 5 countries attracting Chinese acquisitions in the EU account for more than 67% of deals (Figure 9.6). The top EU destination, Germany (DE), accounts for 26% of deals, followed by Spain (ES), which received slightly more than 13% of Chinese brownfield FDI between 2013 and 2020. Italy (IT) and France (FR) closely follow with 12% and 9%, respectively. The number of Chinese deals reached a peak in 2016 with a total of 199 transactions, of which more than a quarter were destined for Germany, decreasing afterwards by an average of 12% per year until 2021 (Figure 9.6).

Overall, data show that the reduction in Chinese FDI in the EU in the last two years is mostly driven by a fall in the number of deals in the manufacturing sector in the EU countries that attract most Chinese acquisitions.

Figure 9.5: Number of Chinese and Hong Kong M&A deals in EU, top 5 target sectors

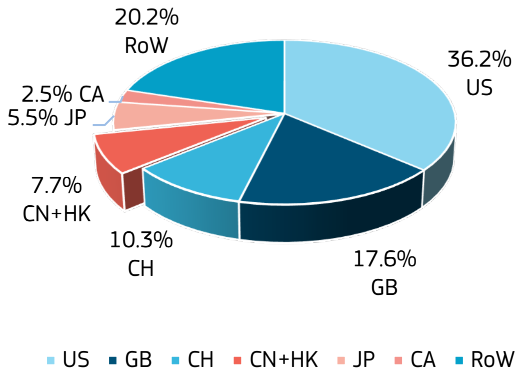
Source: JRC calculations on Bureau van Dijk data (extraction date: May 12, 2022)

Figure 9.6: Number of Chinese and Hong Kong M&A deals in EU, top 5 target countries



Source: JRC calculations on Bureau van Dijk data (extraction date: May 12, 2022)

Figure 9.7: Number of greenfield projects into EU by selected region of origin – cumulative number from 2013 to 2021



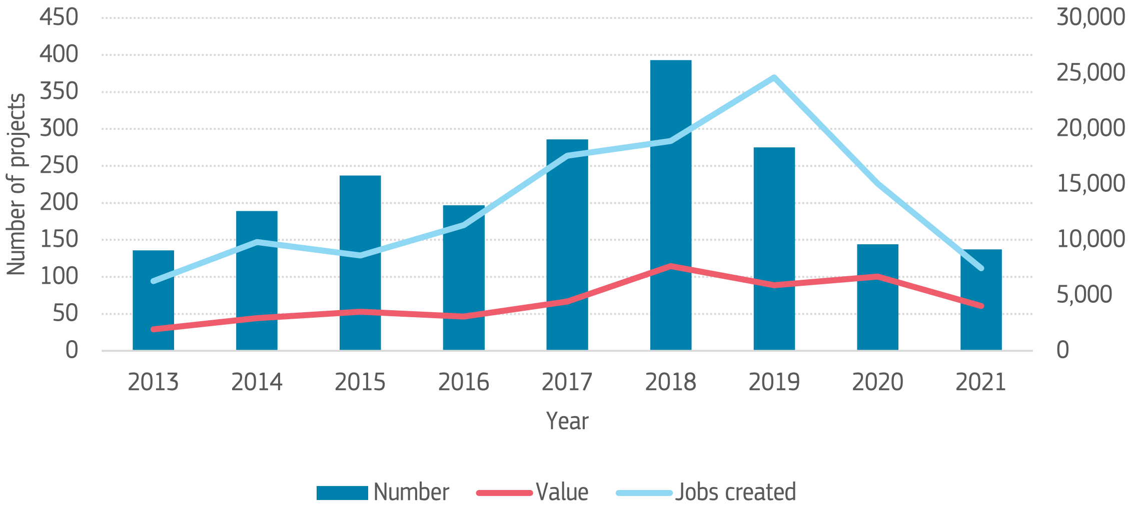
Note: ROW is grouping the rest of the World countries (excluding US, GB, CH, CN+HK, JP and CA)
Source: JRC calculations based on Bureau van Dijk data (extraction date: May 18, 2022)

9.3 Inbound greenfield FDI projects in the EU are alternatives to M&As: China represents 7.7%, ahead of Japan

Between 2013 and 2021, 74% of the foreign greenfield projects[69] into the EU were new realisations. Greenfield investments also include projects that aim at extending production capacity at existing sites (expansion, 14% of greenfield), expanding a physical presence in a foreign market by bringing in a new business line (co-location, 8% of greenfield), or relocating (4% of greenfield). Such projects also target high-tech industries[70].

More than 1 990 Chinese projects were registered in the EU between 2013 and 2021, representing 7.7% of all foreign inward greenfield FDI (Figure 9.7). In terms of M&As, this makes China the second largest non-European greenfield investor in the EU, ahead of Japan (JP) with 1 415 projects. In 2020 and 2021, Chinese projects represented only 7.1% and 5.9%, respectively of EU inbound greenfield. This represents a slowdown in their foreign investments in the EU.

Figure 9.8: Chinese and Hong Kong outbound greenfield investment into EU, number, value of deals and number of announced jobs, 2013-2021



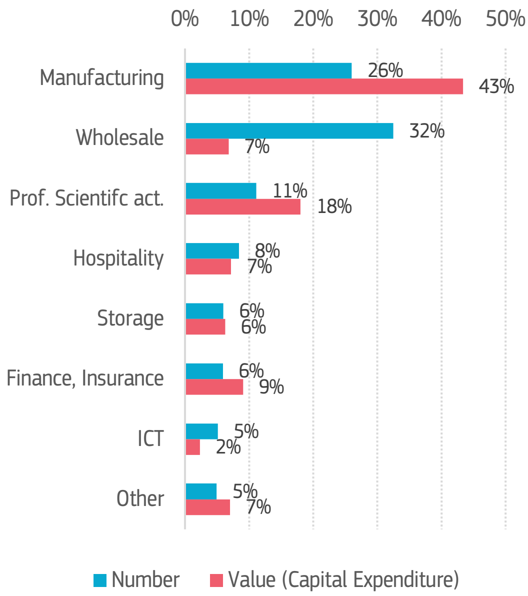
Note: The capital expenditure value and the number of jobs created appears on the right hand side axis. Both the value and the number of jobs created are available, on average, for 94.8% of the projects when considering the modelled estimation proposed by Bureau van Dijk

Source: JRC calculations on Bureau van Dijk data (extraction date: May 18, 2022)

The number of Chinese FDI greenfield transactions in the EU increased from 2013 to 2018, reaching 393 projects in 2018 (Figure 9.8). There was a reversal in this trend in 2019, however, both in the number of projects and in their total value. The number of projects dropped from 393 in 2018 to 275 in 2019, and total value fell from EUR 7.6 billion in 2018 to EUR 5.9 billion in 2019. By contrast, the total number of jobs created by greenfield projects still increases to reach a maximum in 2019 with more than 24,600 jobs.

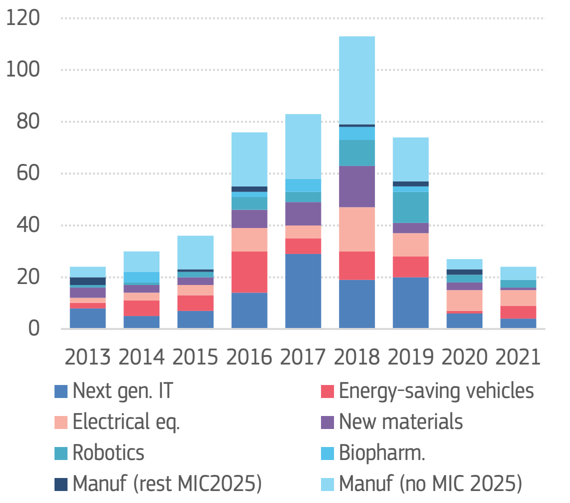
The negative shock due to the COVID-19 pandemic has been stronger for greenfield projects than for M&As. Data for 2020 and 2021 indicate a sharp drop in the number of projects compared to 2019, with a 47.6% fall between 2019 and 2020. This corresponds to a fall in the number of Chinese and Hong Kong projects in the EU from 275 in 2019 to only 144 the following year (Figure 9.8; see Gregori, Martinez Cillero, & Nardo, 2022, for further details).

Figure 9.9: Number and total value of greenfield from China and Hong Kong into EU by sectors, 2017-2021 in percentage terms



Source: JRC calculations based on Bureau van Dijk data (extraction date: May 18, 2022)

Figure 9.10: Number of greenfield from China and Hong Kong into EU in manufacturing, by area of MIC2025



Source: JRC calculations based on Bureau van Dijk data (extraction date: May 18, 2022)

9.4 The majority of Chinese greenfield FDI projects in manufacturing are linked to MIC2025

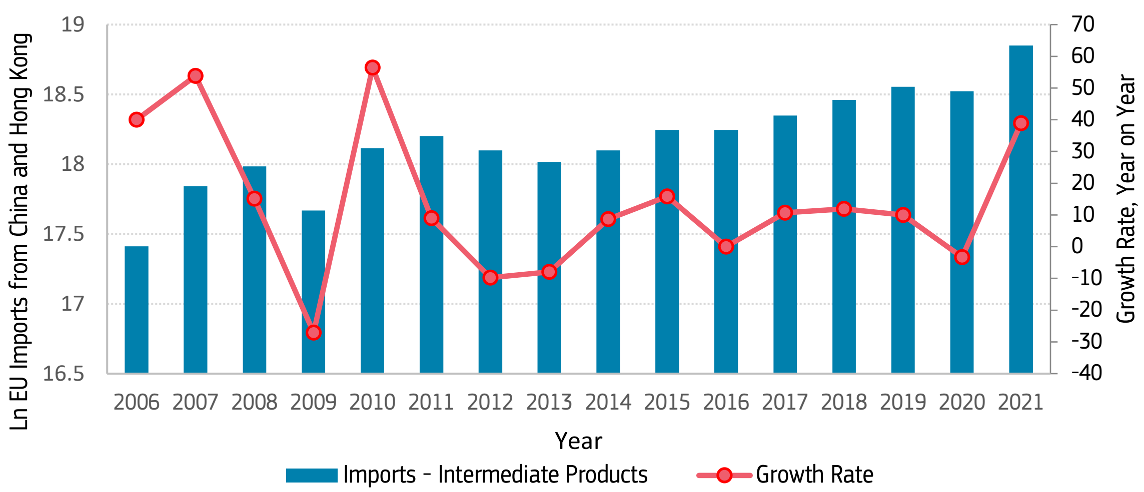
Between 2017 and 2021, manufacturing was the sector with the second highest number of Chinese FDI greenfield projects in the EU (Figure 9.9). The sector accounted for a quarter of all projects. The wholesale sector attracted the highest number of projects (32% of the total), and professional and scientific activities were third, with 11% of projects. Manufacturing was, however, the leading sector in terms of total project value. Greenfield investments enable foreign investors to access a domestic market by building a new site. The investment's location, the skills of the available labour force and the business environment (e.g. the presence of industry clusters) are therefore key factors in a successful project.

As an alternative to M&As, Chinese investors are focusing on opportunities in manufacturing sites linked to the MIC2025 strategy (Figure 9.10).

9.5 MIC2025 investments represented around 75% of all Chinese manufacturing greenfield projects in the EU in 2018 and 2021

Among MIC2025 investments, next generation IT is the largest sector, with 31% of MIC2025 greenfield projects into the EU in 2019, and 50% of the total value. Greenfield projects included investments from companies involved in telecommunications, especially 5G, such as two of the largest providers of telecoms equipment -ZTE and Huawei- and Dahua, a provider of surveillance equipment[71]. Energy-saving-vehicles and electrical equipment follow, representing 17% and 18, respectively, of MIC2025 greenfield projects in the EU.

Figure 9.11: EU imports of intermediate products from China and Hong Kong (in logarithms) and year on year growth rates on the right axis, 2006-2021



Note: Intermediate products are identified according to the BEC classification

Source: JRC calculations based on Eurostat´s COMEXT product-level data on imports from China and Hong Kong

9.6 EU imports of Chinese intermediates bounced back in 2021

A close link connects trade flows to FDI deals (Aviat and Coeurdacier, 2007; Belke and Domnick, 2020). Cross-border investments can be seen either as a consequence of international trade or as an alternative strategy that firms can pursue to reach customers located in foreign markets. Recent contributions (Hoekman et al., 2015; UNCTAD, 2020) relate the reduction in FDI flows at the global level to a slowdown in the pace of economic integration between the major global economies. Evidence shows that the exceptional speed at which globalisation occurred between 1986 and 2008 has been followed by a general slowdown in global integration (Antràs, 2020). Changes in government attitudes to economic integration in several developed economies, as well as medium-run trends in technological change, led to a general restructuring of global value chains (GVCs). Over the last fifteen years, supply chains became shorter, more diversified (UNCTAD, 2020) and more oriented towards regional markets (Ciani and Mau, 2020). The open strategic autonomy approach to trade policy, recently proposed by the EU institutions, is a policy response inspired by these developments.

Data on trade flows in intermediate products between China and Hong Kong and EU countries describes the linkages between European and Chinese production chains in the manufacturing sector. Figure 9.11 shows that GVC integration between the EU and China took place at a slower rate in recent years than it did at the beginning of the 2000s.

Indeed, EU imports of intermediate products grew, on average, by more than 36% between 2005 and 2008, but lost speed in recent years with a growth rate below 6% between 2018 and 2020. Imports of intermediate products bounced back in 2021, reflecting the expansionary phase experienced by all major economies after the easing of restrictions due to the COVID-19 pandemic.

9.7 EU high-tech imports and M&As from China keep on increasing

The relationship between horizontal FDI and trade integration can be first investigated using information on Chinese M&A deals in the EU, and EU imports from China in the same industrial sector. Within NACE sectors, the partial correlation between these two variables is positive and significant, confirming the complementarity between trade integration and Chinese horizontal FDI in the EU at the sectoral level[72].

The close link between trade integration and FDI is supported by the data displayed in Figure 9.12, which reports information on EU imports from China and M&A deals with a Chinese acquirer in high-tech and low-tech sectors[73]. Interestingly, the reduction in M&A deals in high-tech and low-tech sectors coincides with a slowdown in trade flows for both groups, starting from 2018. The average growth rate in imports of low-tech products fell from 10% in 2014-2015 to 4% in 2018-2019. The average growth rate in imports of high-tech products reported a similar reduction, from 13% in 2014-2015 to 7% in 2018-2019[74].

Data also shows that the number of Chinese M&A deals involving EU firms operating in high-tech sectors has been higher than investments in low-tech sectors in the period 2013-2021. At the same time, EU imports from China in high-tech sectors have been higher than imports in low-tech sectors from 2013 onwards. We highlight that the increase in EU imports from China observed in 2021 can be mainly ascribed to high-tech goods.

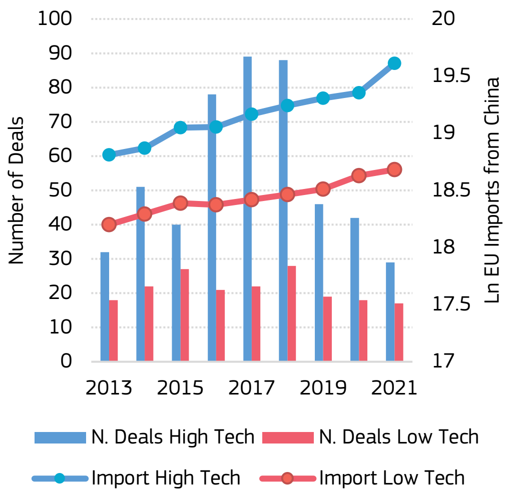
A similar conclusion can be drawn from the data for those industrial sectors considered as strategic by the Chinese government according to the MIC2025 strategy (Figure 9.13). The average growth rate in EU imports for MIC2025 sectors decreased from 13% in 2014-2015 to 7% in 2018-2019. Chinese M&A deals in these sectors went down by 48% in 2021 compared to 2019.

Evidence presented in Figures 9.12 and 9.13 confirms the association between trade integration and FDI flows in the same industrial sectors, thus showing that the recent decline in M&A deals from China can be linked to a reduction in the pace of trade integration between China and EU.

Following arguments that stress the role of vertical FDI, Chinese acquirers should target European firms operating in sectors which are strategic for their performance given their sectoral activities (see Box 2). For instance, Chinese investors might pursue strategies to control the stages of the production chain that can guarantee control over a larger portion of value added. If this occurs, FDI deals between Chinese and European firms operating in different NACE sectors should be observed.

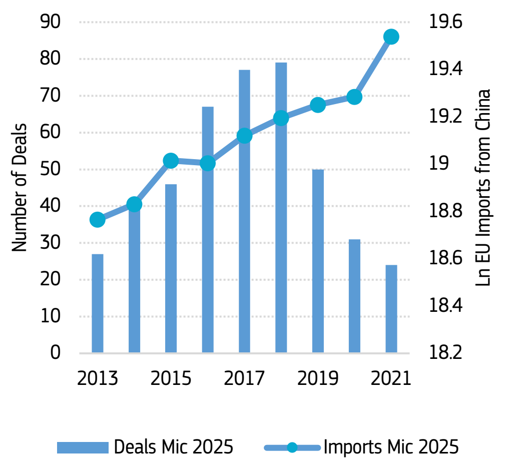
Figure 9.14 presents information on the primary NACE sector in which the acquiring and the target firm operate, relying on data for the period 2013-2021. The figure shows that Chinese acquirers often target European firms operating in industrial sectors which can be placed upward (input suppliers) or downward (output customers) with respect to their position in the supply chain. Indeed, squares located outside the diagonal of the graph show that 82% of Chinese acquirers invest in European firms operating in different sectors of the economy. This holds true even without considering acquisitions by Chinese holding companies, and other financial activities (NACE sectors 64.20, 64.99) which, by definition, are more likely to acquire other companies operating in different industrial sectors.

Figure 9.12: EU imports from China and Hong Kong (in logarithms) and number of Chinese (plus Hong Kong) M&A deals in high-tech and low-tech sectors, 2013-2021



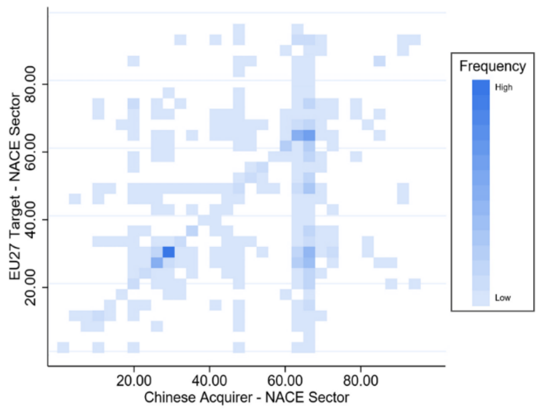
Note: High-tech and low-tech sectors are defined according to the Eurostat classification. NACE sectors in the medium-high technological intensity group are included in the high-tech group, while sectors in the medium-low technological intensity group are in the low-tech group. Intermediate and final products are included both among high-tech and low-sectors.
Source: JRC calculations based on Eurostat's COMEXT data on imports from China and Hong Kong and on Bureau van Dijk data on M&A deals in EU countries made by firms based in China or Hong Kong

Figure 9.13: EU imports from China and Hong Kong (in logarithms) and number of Chinese (plus Hong Kong) M&A deals in MIC 2025 sectors in the EU, 2013-2021



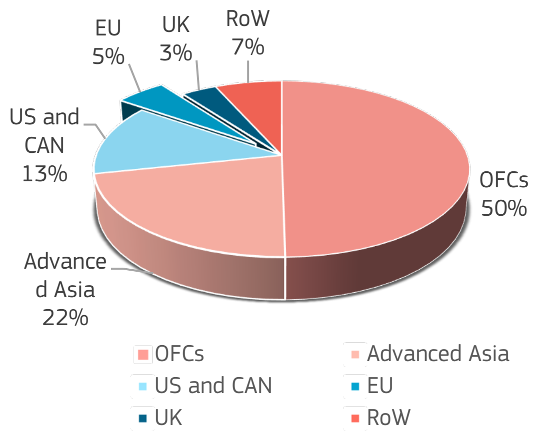
Source: JRC calculations based on Eurostat's COMEXT data on imports from China and Hong Kong and Bureau van Dijk data on M&A deals in EU countries by firms based in China or Hong Kong

Figure 9.14: NACE Sector of Chinese Acquirer and NACE Sector of EU Target firms in M&A deals, 2013-2021



Note: NACE industrial classification. 01-04, Agriculture, forestry and fishing. 05-09, Mining and quarrying. 10-34, Manufacturing. 35-39, Water and electricity services. 41-40, Construction. 45-47, Wholesale and Retail. 49-53, Transportation and storage. 55-56, Accommodation and food activities. 58-63, Information and communication. 64-66 Financial and insurance activities. 68, Real estate activities. 69-75, Professional, scientific, and technical activities. 77-82, Administrative and support activities. 84, Public administration and defence.
Source: JRC calculations based on Bureau van Dijk data on M&A deals in EU countries by firms based in China or in Hong Kong

Figure 9.15: Number of M&A deals in China and Hong Kong by geographical origin, 2013-2021



Source: JRC calculations on Bureau van Dijk data. (extraction date: May 19, 2022)

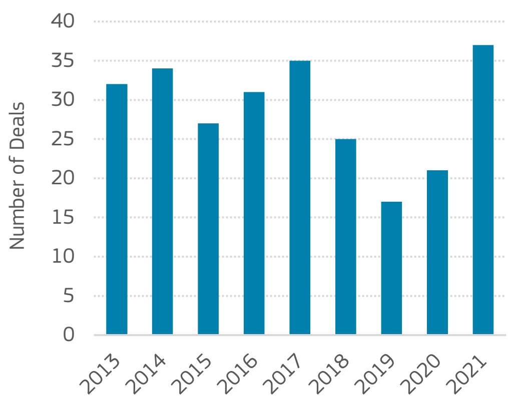
9.8 The EU is the 4th biggest investor in China and Hong Kong

The magnitude of FDI inflow to China and Hong Kong from EU countries is relatively small compared to other economies. Between 2013 and 2021, 22% of deals in China originated from investors based in Advanced Asia (i.e. Japan, Singapore, Taiwan, South Korea), and 13% from the US or Canada (CAN). It is notable that half of FDI taking place in China and Hong Kong involves acquirers based in offshore countries (OFC) (see Box 2 below on the role of OFC in Chinese investments). M&A deals involving investors based in EU countries represented 5% of deals between 2013 and 2021 (Figure 9.15).

In the years 2013 to 2021, 259 EU deals were recorded, of which about half were minority acquisitions, while in the same period more than one thousand deals targeting firms in the EU involved Chinese acquirers (Figure 9.16). The number of EU M&A deals in China was stable up to 2017, decreasing in the following two years. In 2021, they regained momentum compared to activity in 2018-2020, outperforming the previous peak year of 2017.

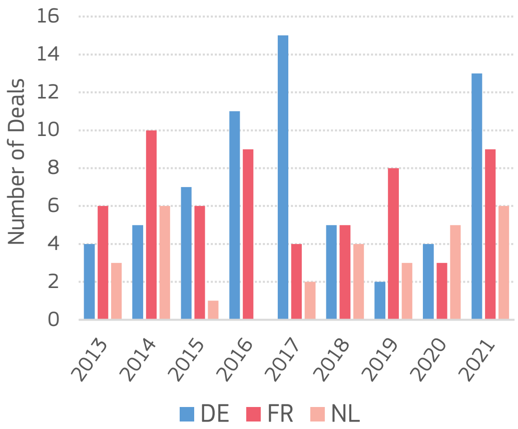
Still, the total monetary value of M&A deals by EU investors increased remarkably, from EUR 0.8 billion in 2013 to almost EUR 3 billion in 2021, showing a higher value per transaction.

Figure 9.16: Number of EU M&A deals in China and Hong Kong



Source: JRC calculations on Bureau van Dijk data. (extraction date: May 12, 2022)

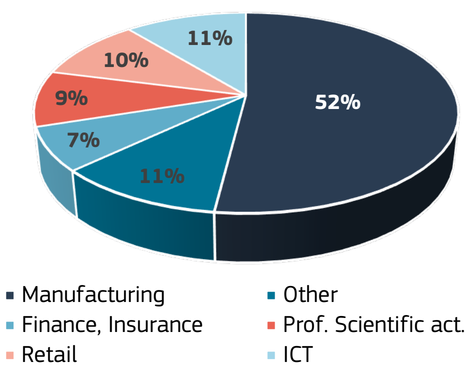
Figure 9.17: Large EU countries investing in China and Hong Kong by number of M&A deals, 2013-2021



Note: EU countries reporting at least five deals in China and Hong Kong in 2021 are included
Source: JRC calculations on Bureau van Dijk data. (extraction date: May 12, 2022)

Figure 9.17 shows that from 2013 to 2021, Germany (DE), France (FR) and the Netherlands (NL) were the main EU investors in China with more than 60% of all EU deals. Furthermore, looking at the sector of the target company (Figure 9.18), in the period 2013-2021 EU countries invested mainly in the manufacturing sector (52% of total number of deals), followed by ICT (11%) and retail (10%).

Figure 9.18: Top EU countries investing in China and Hong Kong by target sector's number of M&A deals, 2013-2021



Source: JRC calculations based on Bureau van Dijk data (extraction date: May 19, 2022)

9.9 Large disparity between the EU and China in jobs created by greenfield FDI in manufacturing

With the creation of new infrastructures or the expansion of existing sites comes the positive economic outcome of job creation and capital expenditure[75].

A particularity of FDI greenfield projects (compared to M&As) is that their description often includes the number of jobs created and the additional capital they are bringing to the receiving economy[76]. This information is useful in assessing reciprocity in EU-China relations for FDI greenfield projects.

Reciprocity does not mean parity. In 2019, the growth of China's GDP was four times higher than that of the EU according to the World Bank. In 2016 there were 77.5 million firms registered in China, according to the Chinese Administration for Industry and Commerce, almost three times more than what Eurostat registered in the EU in 2017.

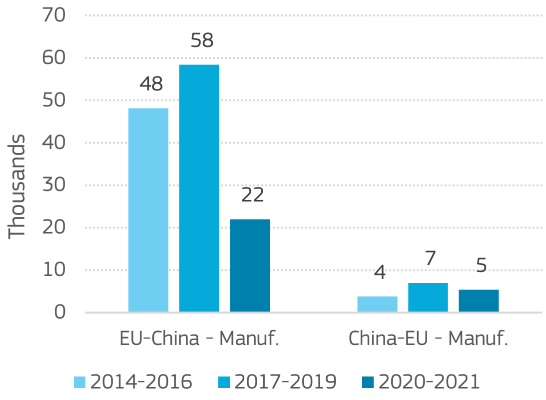
For its importance in EU-China relations, manufacturing is selected for further analysis (Figure 9.19). In absolute terms, between 2014 and 2021, European firms created 363 000 manufacturing jobs in China. Average job creation per year was higher in the period 2017-2019 (58 400 jobs created) than between 2014 and 2016 (48 000 jobs), showing EU firms growing interest in the Chinese economy.

As expected, Chinese projects bring fewer jobs into the EU via greenfield investments (around 43,000 jobs in the EU were announced by Chinese firms between 2014 and 2021). From 2017 to 2019, on average 7 000 new jobs per year were created by Chinese greenfield manufacturing projects (3,800 per year in 2014-2016). For both flows, the average yearly job creation dropped for in 2020 and 2021 period, as expected due to the pandemic restrictions.

From 2017 to 2019, , the EU created almost seven times more jobs in China than China created in the EU. This is partly due to the difference in labour cost. The Chinese manufacturing labour cost per hour was estimated at USD 5.71 in 2019[77], five times less than that of the US (USD 27.57) and 5.4 times less than in the EU (EUR 27.7)[78].

However, data also show differences in the Chinese strategy and objectives, which might use alternative modes of investment such as M&As, venture capital (VC) or exports to enter the EU manufacturing market.

Figure 9.19: Number of jobs created by greenfield – Manufacturing. China includes transactions from Hong-Kong



Source: JRC calculations on Bureau van Dijk data (extraction date: May 18, 2022)

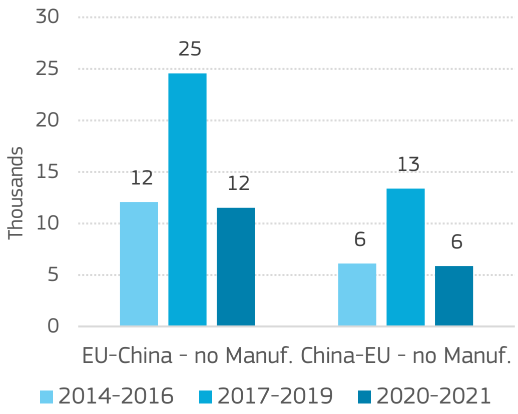
These strategies are sometimes not available to EU companies investing in China due to the constraints imposed by the Chinese authorities on foreign investment in certain sectors/technologies (see chapter Trade and Reciprocity). Reciprocity in capital expenditures is more balanced than for jobs, for every euro invested by China in the EU, 7 euro is invested by the EU in China via greenfield projects.

As far the non-manufacturing sectors are concerned (Figure 9.20), 133 000 jobs were created by EU firms in China between 2014 and 2021 and 70 000 jobs by Chinese firms in the EU in the same period.

Generally speaking, all MIC2025 sectors show higher job creation by EU firms in China than the reverse case. The largest MIC2025 sectors in which the EU creates jobs in China are new materials and energy-saving vehicles, with more than 18 000 and 12 000 jobs announced on average, respectively, between 2017 and 2021 (Figure 9.21). For new materials, the EU announced 32.4 times more jobs in China than the reverse. For energy-saving vehicles, the EU created 21.2 times more jobs in China.

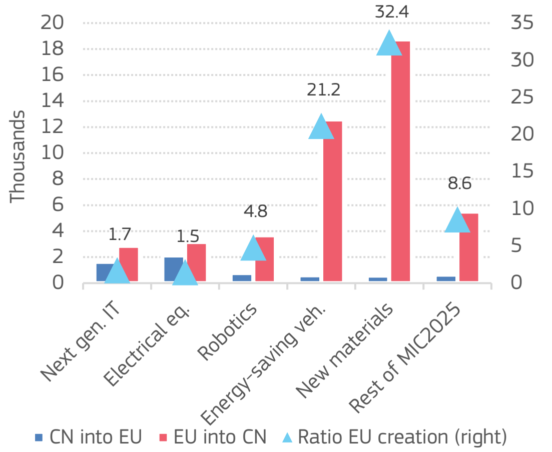
On capital expenditure, most MIC2025 sectors (except for electrical equipment) showed higher capital injections by EU firms in China than the reverse. The ratio of the EU injection is 10.8 for new materials and 25.8 for energy-saving vehicles, on average over 2017-2021 (Figure 9.22). This means that for every euro invested in the EU by Chinese and Hong Kong investors, EUR 10.8 is invested by EU investors in China in the new materials sector. For electrical equipment, the ratio is 0.8, meaning that EU firms are bringing less capital into China than Chinese firms invest in Europe.

Figure 9.20: Number of jobs created by greenfield - excluding Manufacturing. China includes transactions from Hong-Kong



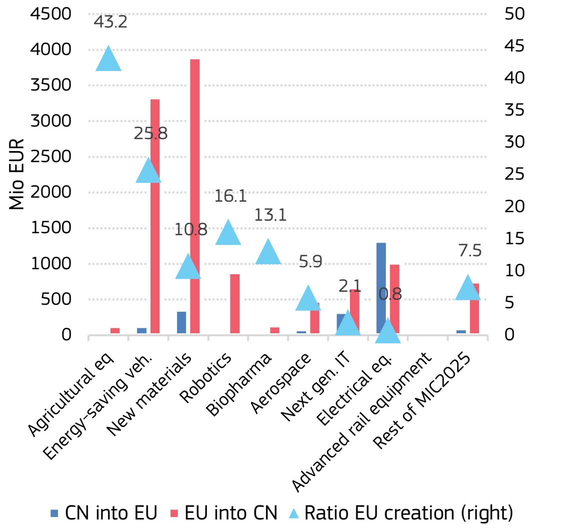
Source: JRC calculations on Bureau van Dijk data (extraction date: May 18, 2022)

Figure 9.21: Number of jobs created in the relation EU-China and Hong Kong created by greenfield in MIC2025, on average 2017-2021, on the left axis. Factor (ratio) of jobs creation of the EU into China versus China into EU on the right axis



Notes: When the ratio of EU creation is higher than 1, EU creates more jobs in China than China created in the EU
Source: JRC calculations on Bureau van Dijk data (extraction date: May 18, 2022)

Figure 9.22: Capital injected in the relation EU-China and Hong Kong created by greenfield in MIC2025, in average 2017-2021, on the left axis. Factor (ratio) of capital expenditure of the EU into China versus China into the EU on the right axis



Notes: When the ratio of EU injection is higher than 1, the EU injects more capital in China than China in the EU
Source: JRC calculations on Bureau van Dijk data (extraction date: May 18, 2022)

Box 2: The reorganisation of global value chains behind trends in M&A deals

Studies investigating the linkages between FDI patterns and trade flows propose two main explanations for direct investment abroad, both guided by the same goal: to save costs and increase efficiency. The first suggests that, instead of shipping its goods, a firm may want to produce directly in the market where consumers are located and save on transportation and other trade-related costs. This is defined as horizontal FDI (Helpman et al., 2004).

Alternatively, companies may invest in locations where they can secure workers and infrastructure at a lower cost, integrate better with different stages of the production chain, or have fiscal convenience. In this case, the comparative advantage of different countries (fiscal regimes, availability of a skilled workforce, existing logistic infrastructure, lighter administrative requirements, rule of law, etc.) guides the decision on the investment location for companies pursuing vertical FDI.

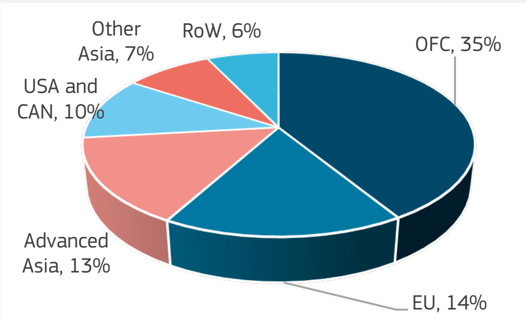
Box 3: Chinese acquisitions across the world and the role of offshore countries

While the presence of Chinese investors in the EU has been increasing in recent years (as described in section 1.1), a focus on worldwide Chinese FDI provides a comprehensive understanding of the attractiveness of the EU for China. This box focuses on Chinese outbound FDI (i.e. deals that lead to the acquisition of a final stake above 10% of the target company) in the period 2013 to 2021.

In the last 9 years, we recorded 5 626 outbound deals by Chinese-controlled companies, primarily targeting offshore countries (OFCs, 35% of total deals), followed by the EU (14%) and advanced Asian countries (i.e. Japan, Singapore, Taiwan, South Korea, 13%), as detailed in Figure 9.23a.

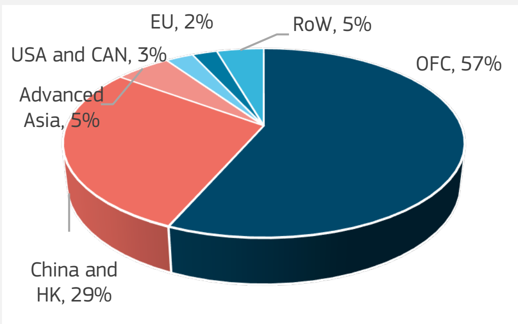
Interestingly, OFCs are the top destination, and the literature suggests that these locations are able to attract financial flows thanks to low-tax incentives (Dowd et al, 2017; Fatica and Gregori 2020) or secrecy rules (Johannesen and Zucman, 2014). In addition, considering that investments from OFCs (compared to non-OFCs) towards the EU are negatively affected by FDI screening procedures (Gregori and Nardo, 2021), a focus on offshore Chinese FDI can provide valuable insights. We therefore investigate these transactions, namely deals made by companies located in OFCs with an ultimate global owner in mainland China or Hong Kong, by geographical destination in the period 2013 to 2021. We find that of a total of 1,084 deals, most were redirected to other OFCs (57%), or back to China (29%). Only 2% of deals were directed towards EU countries (Figure 9.23b). Besides the usual reasons to locate in offshores, there is evidence that OFCs are exploited as a domicile for companies listed in mainland China or Hong Kong (or even overseas) thanks to a lighter regulatory burden. Overall, the main sectors receiving Chinese funds channelled via offshores are Finance and Insurance (25%), Manufacturing (19%), Construction (12%) and ICT (11%).

Figure 9.23a: Chinese outbound FDI by geographical destination, 2013-2021



Source: JRC calculations on Bureau van Dijk data (extraction date: May 23, 2022)

Figure 9.23b: Offshore Chinese outbound FDI by geographical destination, 2013-2021



Source: JRC calculations on Bureau van Dijk data (extraction date: May 23, 2022)

MERGERS & ACQUISITIONS AND TECHNOLOGICAL DIVERSIFICATION

10.1 Acquisition strategies to gain technological capabilities

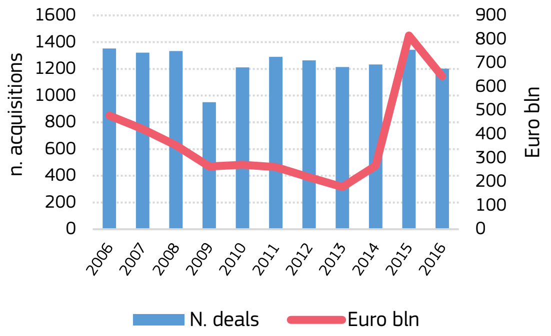
Large companies face difficulties in keeping up with the ever-increasing pace of technological change. Technological acquisitions are a popular development strategy for firms to remain competitive. However, European and Chinese multinational corporations (MNCs) may differ in their acquisition strategies.

While EU companies may be more oriented towards consolidating activities in sectors where they are already competitive, Chinese ones seem to try to expand their activities (McKelvey & Bagchi-Sen, 2015). Their different growth strategies could be reflected in how they choose their targets. For example, EU companies may acquire targets that are more technologically similar, while Chinese MNCs could select targets with unrelated technologies. As found in Pugliese et al. (2019), the degree of coherent technological diversification — i.e., the addition of technology domains that are functionally adjacent to the existing technology stock of a firm — is associated with better company performance in terms of productive efficiency.

The relationship between the performance of the acquiring MNCs and the similarity between the technological portfolios of the acquiring and target firms is explored using tools borrowed from complexity science (Hidalgo and Hausmann, 2009; Tacchella et al., 2012, Zaccaria et al., 2014; Tacchella et al., 2018). Specifically, we investigate whether the accumulation of coherent knowledge and capabilities via M&A lead firms to experience advantages in terms of increased labour productivity. To this end, data on acquisitions from Zephyr (Bureau van Dijk) are matched to data on patents from PATSTAT and to data on the 2017 EU Industrial R&D Investment Scoreboard (JRC), whose companies (as shown in Figure 10.1) sign acquisition deals worth hundreds of billions of euro every year.

Over the period 2006 to 2016, these top R&D investors made around 10 000 acquisitions[79]. Figure 10.1 shows the number and value of acquisitions made by companies included in the scoreboard each year. Altogether, these acquisitions represent one sixth of the world's total M&A value, however this is a lower bound estimate as many deals lack deal values and we have excluded capital increase deals.

Figure 10.1: Number and value (EUR billion) of acquisitions of top R&D investing companies.



Source: JRC calculations – Zephyr and Scoreboard data

10.2 Coherent technological diversification

Firms, especially large MNCs, often deal with a number of products, based on heterogeneous technologies, whose relatedness may vary significantly. When a firm adds a new project to its research portfolio, the scope of its knowledge base will increase, but coherence may either increase or decrease. If the new project involves a technology that is related to the existing firm's knowledge stock, coherence will increase. By contrast, the introduction of a radically new technology will decrease technological coherence[80].

Empirical studies suggest that technologically coherent diversification contributes positively to a firm's economic performance (see Knecht, 2013). In a different way to the standard economic approach to measuring the degree of technological coherence, the present analysis adopts the economic complexity approach (Hidalgo and Hausmann, 2009; Tacchella et al., 2012, Zaccaria et al., 2014; Tacchella et al., 2018; see also chapter 5. Economic complexity of the EU, China and the US). Specifically, the analysis uses a network-based measure of coherence proposed by Pugliese et al. (2018), which makes it possible to break down data on acquirers and targets and group patents into clusters of functionally related technological fields[81].

With this new methodological approach, the chapter looks at the relationship between the MNCs' labour productivity and their degree of technologically coherent diversification, resulting from the acquisition of targets with patents.

10.3 The biggest R&D investors from the EU and US engaged in more M&A deals than their Chinese counterparts between 2007 and 2016

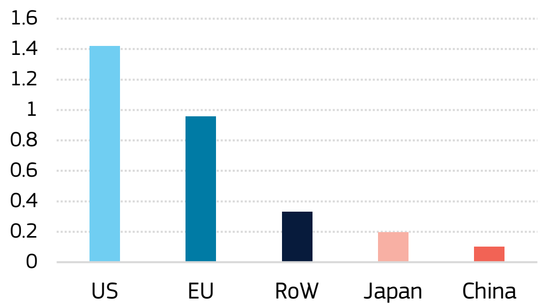
Once the data on acquisitions is matched with data from the R&D scoreboard panel data (2007-2016), the total number of acquisitions amounts to roughly 8 000. The world's largest R&D investors are the US and the EU. It is not surprising, then, that the majority of M&A deals come from these two blocks. However, it is interesting to observe that, even when we look at the average number of acquisitions per firm (see Figure 10.2), US and EU companies still outperform their Chinese counterparts.

10.4 Chinese MNCs acquire more domestic firms than EU firms and EU MNCs are more technologically diversified

Figure 10.3 shows the flows of acquisitions by acquiring (left) and target (right) country. Chinese MNCs predominantly acquire domestic firms (70% of acquisitions) and relatively few European ones. By comparison, US and EU firms acquire domestic companies in, respectively, 64% and 61%, of cases.

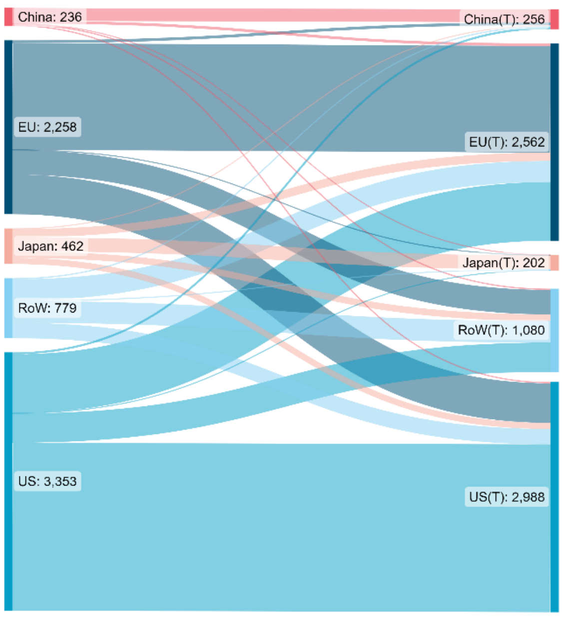
To construct a measure of coherent technological diversification between the portfolios of acquiring and target firms, we consider the subsample of M&A deals where both the acquirer and target have patents. Less than 20% of acquisition deals involved technologically active acquirers and targets.

Figure 10.2: Average number of M&A deals per acquiring firm and per year



Source: JRC calculations – Zephyr and Scoreboard data

Figure 10.3: Number of acquisitions, by acquiring and target country



Source: JRC calculations – Zephyr and Scoreboard data

10.5 Acquisitions of EU patenting firms by China's MNCs represent 15% of Chinese purchases

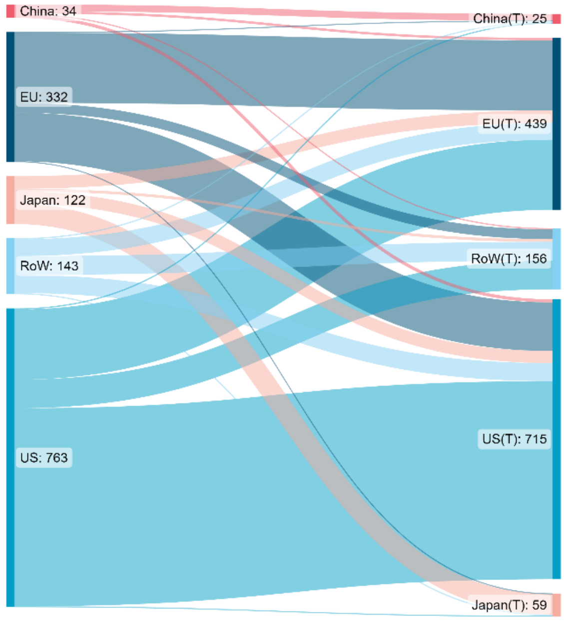
Figure 10.4 shows the same flows of acquisitions as in Figure 10.3, but restricted to the subsample of patenting firms. US MNCs have the largest number of technologically oriented acquisitions. Of the 34 acquisitions made by Chinese MNCs, 6 targeted EU companies and 8 targeted US companies. Note that acquisition of EU patenting companies by Chinese MNEs represents a small fraction of the EU share of patenting firms (1%), but a significant share from the perspective of Chinese purchases (18%). In general, the number of Chinese acquisitions of patenting and non-patenting firms is much smaller compared to the US and EU.

Also for patenting firms, Chinese M&As are strongly oriented towards domestic firms, amounting to 70% of all acquisitions – against 64% for US and 61% for EU firms.

Figure 10.5 shows that most technology-oriented acquisitions are technologically coherent with the acquirer's technology base (57.5%). However, very few MNCs acquire technologies that are already present in their company (less than 8%) and almost 35% of acquisitions are not coherently technologically diversified.

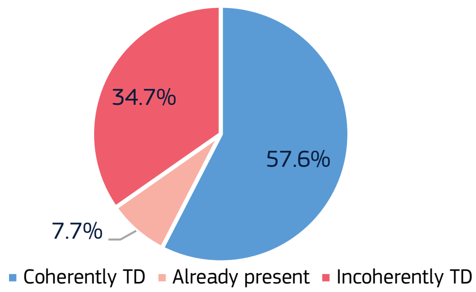
Looking at different geographical areas (Figure 10.6), with a 43% share, Chinese MNCs seem to have an acquisition strategy more geared towards incoherent diversification, compared to EU firms, which are the ones with the highest share of coherently diversified acquisitions.

Figure 10.4: Number of acquisitions, by acquiring and target country: Subsample of patenting firms



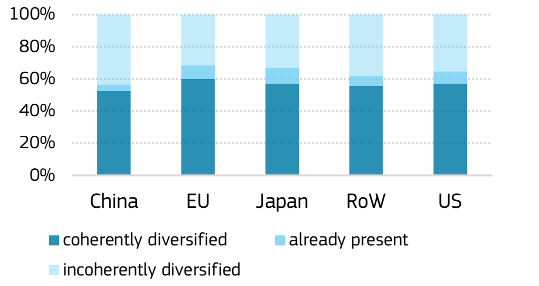
Source: JRC calculations – Zephyr and Scoreboard data

Figure 10.5: Share of acquisitions by technological diversification of the acquirers' patent portfolio



Source: JRC calculations – Zephyr, Patstat and Scoreboard data

Figure 10.6: Share of M&A deals by technological diversification of the acquirers' patent portfolio by geographical region



Source: JRC calculations – Zephyr, Patstat and Scoreboard data

10.6 Labour productivity is supported by technological diversification

To test if these different technology acquisition strategies are linked to economic performance, we performed a simple panel data regression analysis, using labour productivity growth as an indicator of performance.

For the full sample of acquiring firms, there is no statistically significant relationship between diversification strategies and their labour productivity. However, when splitting the sample into two by the median value of net sales growth rate, a significant pattern emerges.

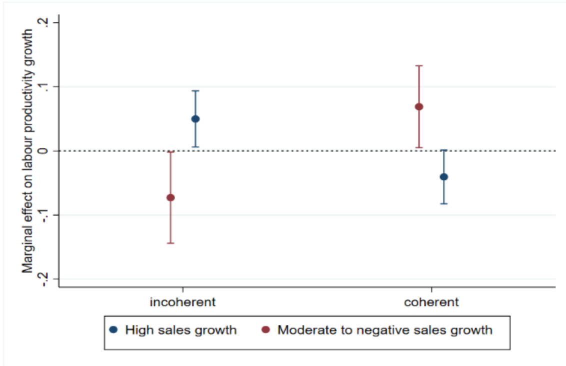
When a firm has negative to moderate sales growth (up to 5% growth rate), only coherent technological diversification is positively related to their productivity growth. Conversely, when sales diminish or stagnate, the acquisition of firms with functionally distant (incoherent) technology has a negative effect on the growth of labour productivity (Figure 10.7).

A plausible explanation is that firms that experience a growth in their sales may be in a better position to buffer the risk of targeting technologies that are unrelated to their technology base. Indeed, drastically diversifying during a favourable period could potentially ensure stabilised earning streams.

Figure 10.8 shows the share of fast-growing firms by geographical area (with a net sales growth rate above the median value). Almost the entire sample of Chinese firms are in the fast-growing category, while Japanese firms lag behind (only 10% are fast-growing).

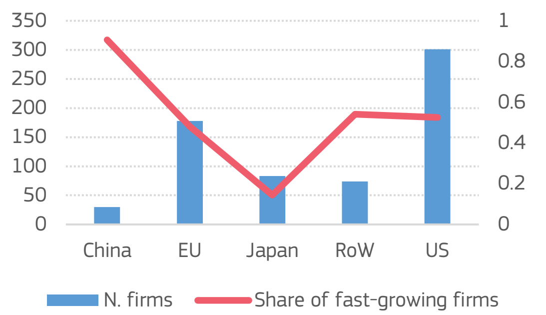
This implies that while Chinese MNCs gain more relative to other MNCs from incoherent diversification, they also lose more in terms of productivity when investing in coherent technological acquisitions. Instead, Japanese firms raise productivity growth by acquiring coherent technologies, as most of these firms are in the negative to moderate sales growth category.

Figure 10.7: Technological diversification and labour productivity growth of acquiring firms



Source: JRC calculations – Zephyr, Patstat and Scoreboard data

Figure 10.8: Number of acquirers by geographical area and share of fast growing firms



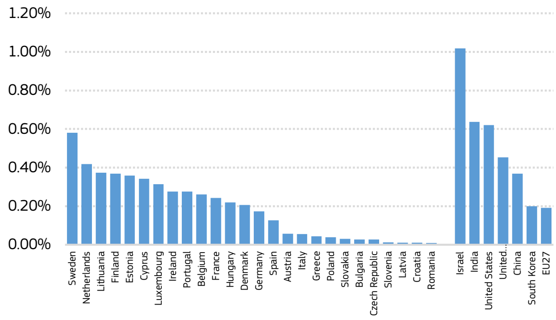
Source: JRC calculations – Zephyr, Patstat and Scoreboard data

11.1 China's average venture capital fund was three times bigger than in the EU in 2010-2014, and five times bigger in 2015-2019

The importance of a vibrant venture capital (VC) industry in supporting growth is widely recognised, and as a result governments across the world have sought to promote the VC industry. But the development of the VC industry in EU countries has been slow and uneven compared to other countries. According to pre-COVID-19 data, the US is the largest VC industry in the world, investing EUR 118 billion in 2019. By contrast, VC investments made by EU countries totalled only EUR 18 billion in 2019, one-sixth of the US total. China has the most active VC market in Asia, investing EUR 47 billion in 2019. On a GDP-adjusted basis, Israel, the US, Sweden and the UK have consistently shown high investment intensities over the years, with Israel's exceeding even that of the US. In Asia, Japan is far behind the US while China and South Korea show a much higher intensity in recent years (Figure 11.1).

Understanding how the EU VC market compares with the US and Chinese market is the first step towards improving the performance of the EU's VC industry. The US VC industry continues to be more developed than the European and Chinese VC industries. There are some big differences in the characteristics of VC funds in the EU and China, and these differences have existed for some time (Table 11.1). Chinese VC funds are larger than those in the EU and the US counterparts, and the gap has not narrowed much over time. VC funds raised in China over 2015-2019 were larger than those raised in the EU and the US from 2010 to 2014. While the EU is catching up with the US, convergence between the EU and China has been limited. The average fund size in China was three times bigger than in the EU in 2010-2014, and five times bigger in 2015-2019. Their bigger size allows Chinese funds to invest larger amounts in each portfolio company on average, while investing in a smaller number of companies.

Figure 11.1: VC investments (% GDP) 2019



Source: JRC elaboration based on Pitchbook data.

11.2 Compared to European funds, Chinese VC funds are less specialised and invest in more sectors

Figure 11.2 shows the proportion of capital invested by VC funds across seven broadly-defined industries. The left hand panel shows the allocation of capital for funds established in the 2010-2014 period and the right hand panel focuses on the most recent funds, established in 2015-2019. In the earlier period the industry defined as information technology received the highest share of investment in all three geographical entities. Healthcare was the second most preferred industry. The remaining industries received considerably smaller shares of investments. If we look at funds

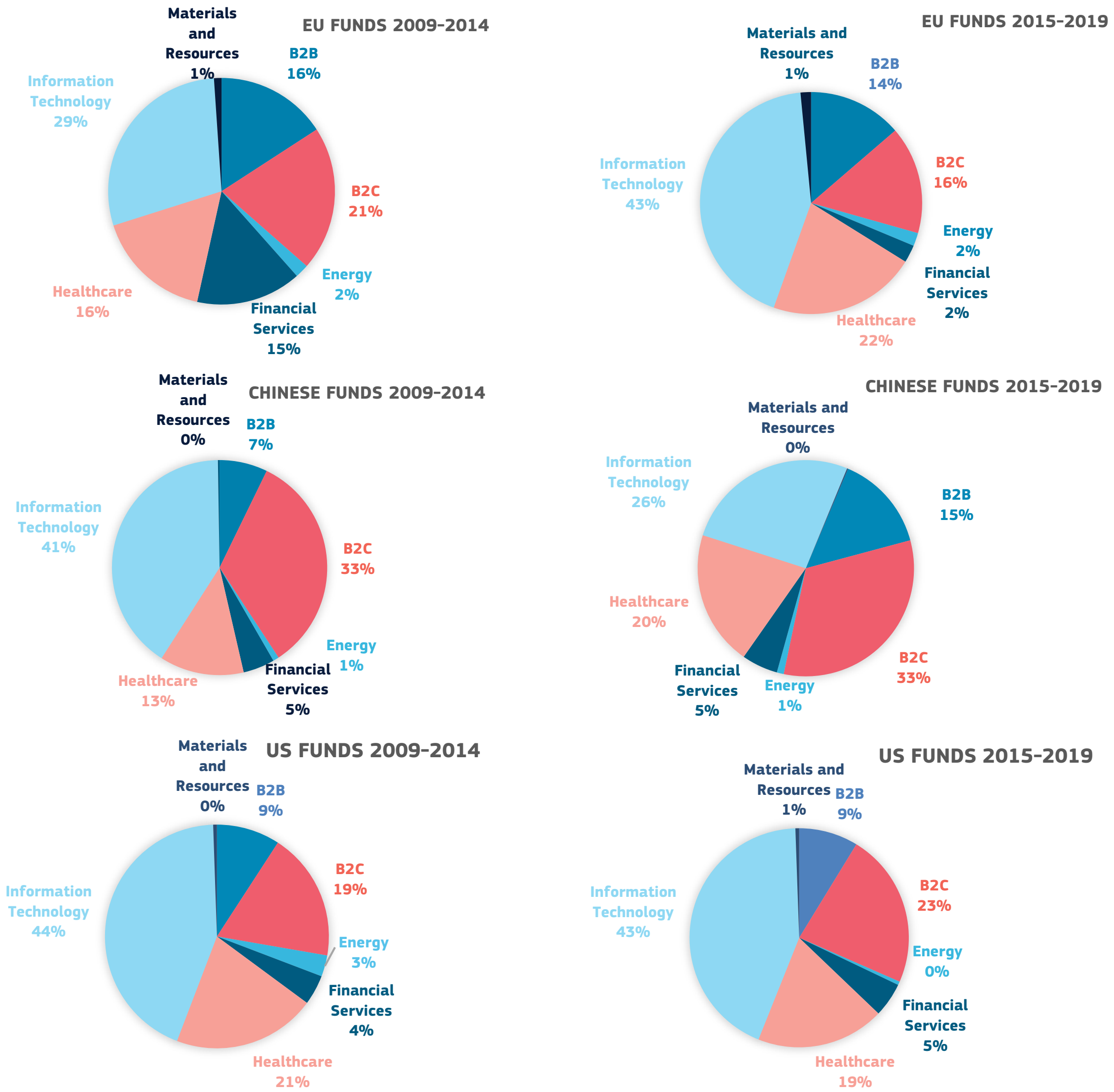
Table 11.1: Key summary statistics

	VC Fund Vintage Year: 2010-2014		
	EU	China	US
Fund size Mean	€50.41M	€150.17M	€101.04M
Fund size Median	€23.69M	€107.18M	€29.11M
Deal count	423	157.60	2063.2
Capital invested Mean	€4.62M	€13.61M	€8.61M
	VC Fund Vintage Year: 2015-2019		
	EU	China	US
Fund size Mean	€107.57M	€541.00M	€129.25M
Fund size Median	€71.52M	€202.65M	€37.58M
Deal count	1066.6	413.2	4437
Capital invested Mean	€8.96M	€50.68M	€18.18M

Source: JRC elaboration based on Pitchbook data

established in the most recent period (2015-2019), there has been a shift of investment away from information technology in China, whereas this industry continues to lead the ranking in the EU and US. In particular, Chinese funds appear to have a much stronger focus on business to consumer (B2C) products and services compared to European funds, which instead invest relatively larger shares in information technology and healthcare. Using a measure of the concentration of investment in an industry or a group of industries, we find that US funds are more specialised than both EU and Chinese funds. Even though from 2015 to 2019 we can observe a trend towards greater specialisation in the EU, there is a reversal of this pattern in China.

Figure 11.2: VC investment by industry and vintage year (China, EU and US)



Note: Business Products and Services (B2B) are products or service transactions exclusively conducted between companies. Consumer Products and Services (B2C) are products or service transactions exclusively conducted between a business and a consumer. Energy sector are all companies engaged in the exploration, production and distribution of energy and the companies that supply products and services specifically to those who operate within the energy sector. Financial services are professional services involving the investment, lending, and management of money and assets for both businesses and individual consumers. Healthcare sector refers to all companies providing medical products or services. The information technology sector includes all companies whose primary focus is the development of software, and hardware, and all companies whose primary focus is on IT consulting, outsourcing or database management. Materials and Resources includes all companies engaged in the production, development, discovery and wholesale of raw materials.
Source: JRC elaboration based on Pitchbook data

11.3 With a 70% domestic investment share in 2015-2019, Chinese VC funds were less internationalised than their EU peers

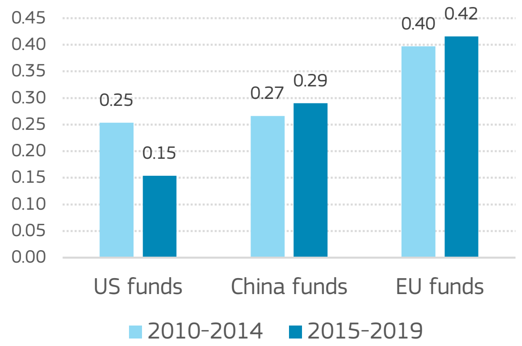
US and Chinese funds have traditionally invested domestically, with less than a quarter of US and Chinese funds raised between 2010-2019 invested in companies outside the US and China (Figure 11.3). By contrast, the majority of EU funds invested outside their home market. The strong preference of US and Chinese funds to invest in their own economies becomes more evident when we consider the amounts invested in each market (Figure 11.4). 75% of all US VC capital raised between 2015 and 2019 stayed in the US, while around 4% went to the EU. The picture is almost the same for China. 71% of all capital invested by Chinese funds went to Chinese companies, while as much as 15% went to the US and only 1% was invested in the EU. EU funds invested a large proportion of their capital in the US (26%), but only 1% in China. As we can see, the situation has changed in recent years.

Overall, this analysis suggests that the EU was not an attractive proposition for US and Chinese VC funds. Instead, the opposite was the case. A much larger share of European VC funds invested in the US than the other way around. While the EU is likely to benefit from the funds it invests in the US, e.g. for the networks it builds and the experience it generates, the small flow in the opposite direction may be a cause for concern.

11.4 EU VC funds increasingly targeted US firms in 2015-2019 and reduced their investments in China from 24% to 1%

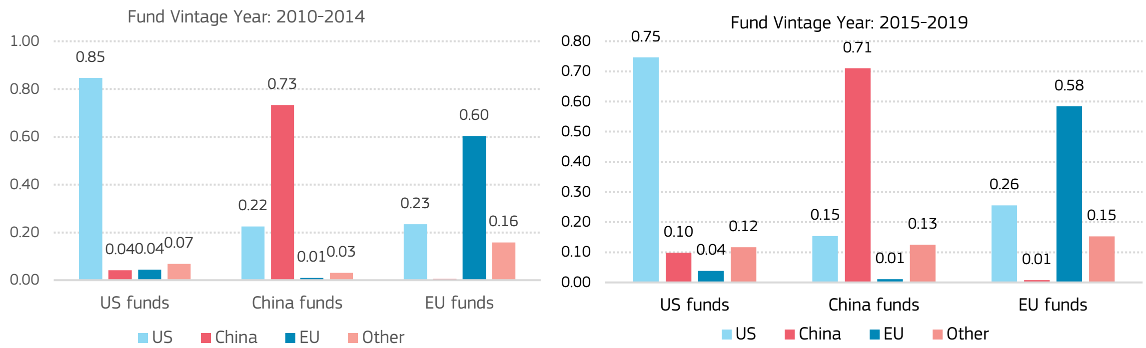
Looking at the geographical destination of VC investments made by EU investors, Figure 11.5 shows that the majority of EU funds invest in US businesses and just a small proportion of their investments are in Chinese companies. It can also be seen that the share of EU VC investments in US companies increased from 39% in 2015 to 43% in 2019, while EU VC funds reduced their investments in Chinese markets from 24% to 1% (Figure 11.5). In line with the previous analysis, Figure 11.6 shows the geographical destination of Chinese VC investments.

Figure 11.3: Proportion of funds investing outside of home country



Source: JRC calculations on Pitchbook data.

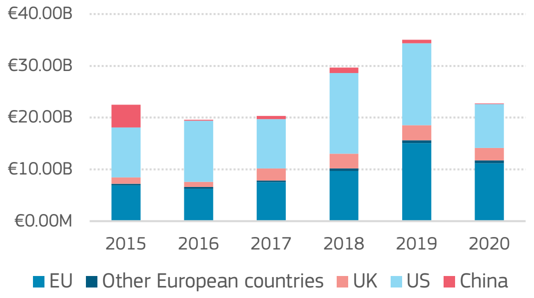
Figure 11.4: Proportion of capital invested into each country



Source: JRC elaboration based on Pitchbook data

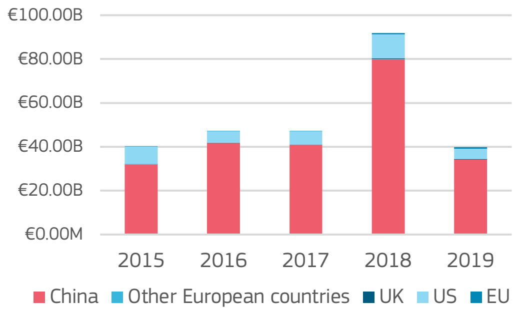
It appears that Chinese VC funds tend to make larger investments in Chinese and US companies, and invest smaller amounts in EU companies. In 2019, less than 2% of Chinese funds made an investment in a European company, while around 12% of Chinese funds have invested in the US.

Figure 11.5: VC investments made by EU investors in EU, other European countries, UK, US and China



Source: JRC elaboration based on Pitchbook data

Figure 11.6: VC investments made by Chinese investors in China, EU, other European countries, UK, and US



Source: JRC calculations based on Pitchbook data

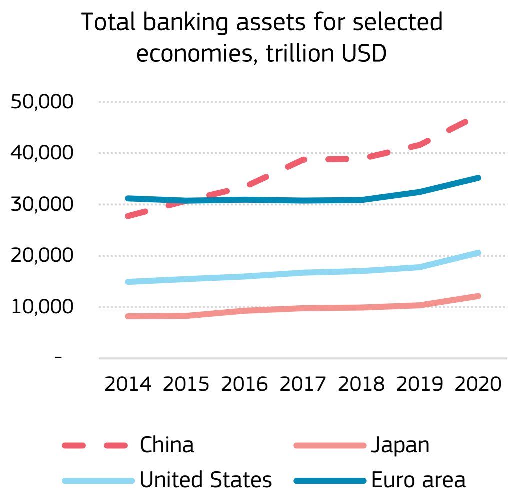
STRUCTURAL VULNERABILITIES TO THE EUROPEAN BANKING AND FINANCIAL SYSTEM FROM CHINA

12.1 China's banking system is the world's largest

The Chinese financial sector is dominated by a banking system that has grown substantially over the last decade and is the largest in the world by holding assets of more than 300% of the country's GDP. Total banking assets have increased to surpass the size of the euro area banking system, creating an interest for the EU and the other main economies in having a stake in a stable Chinese banking system (Figure 12.1).

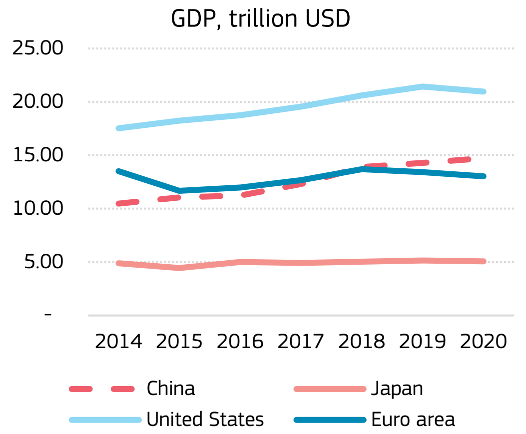
The exponential growth in the Chinese banking sector's assets is linked to China's growth in GDP (IMF, 2018). During the last decade, China's economy became one of the world's largest in terms of nominal GDP (Figure 12.2). Banks are driving the remarkable expansion in credit growth, as Chinese companies heavily resort to bank financing (Bisio, 2020).

Figure 12.1: Banking assets – selected countries



Source: FED, Bank of Japan, ECB, and Statista Research

Figure 12.2: GDP China and selected economies



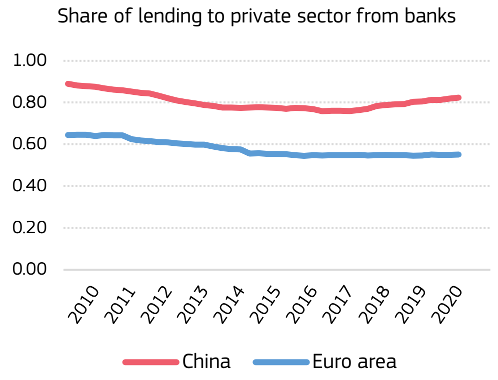
Source: FED, Bank of Japan, ECB, and Statista Research

12.2 Bank lending in China is key, with few firms funded via the stock market

The core business of China's banking system is traditionally concentrated around lending (BIS, 2019). Chinese banks play a major role in supporting the growing Chinese economy with credit, which implies substantial risks to the banking sector in case an economic downturn materialises. Chinese companies indeed heavily rely on banks for financing: with 16 million companies in China, only 3 800 listed companies have obtained their funds via the stock market. In 2020, Chinese banks accounted for around 80% of lending to the private non-financial sector, while in the euro area banks accounted for less than 60% (Figure 12.3).

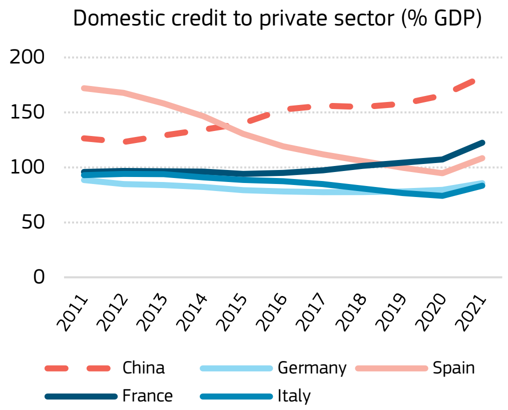
Domestic credit from financial institutions to the private sector has steadily increased over the past decade (Figure 12.4). This is particularly evident when looking at the size of household loans (Figure 12.5). In particular, around 20% of overall household debt is related to mortgages.

Figure 12.3: Private sector lending from banks



Source: BIS and JRC elaboration

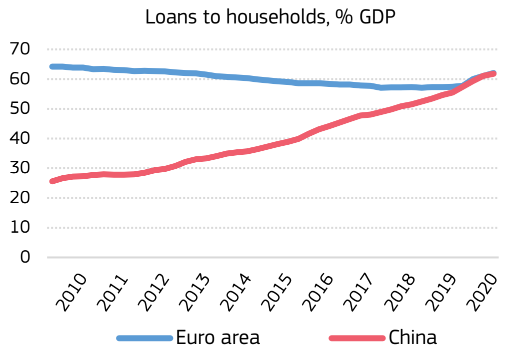
Figure 12.4: Private credit



Source: The World Bank and JRC elaboration

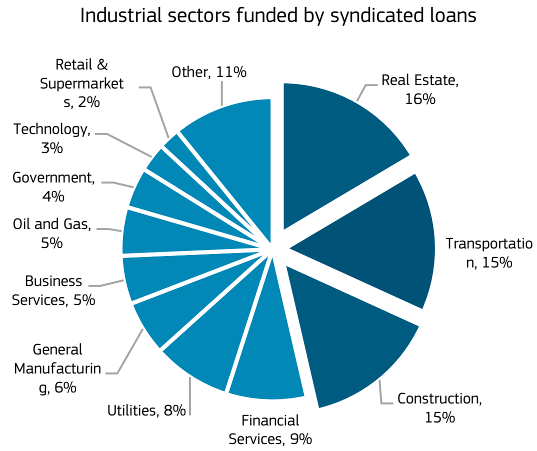
An in-depth analysis of syndicated loans shows the sectors receiving large amount of funds from private borrowers. In the absence of other credit information and, sometimes, even aggregated data, the syndicated loans market is commonly used to measure bank lending policies and their effects. Syndicated loans are in fact an important financing source for non-financial firms, while comprising only a fraction of banks' total lending. Recent information points to five sectors that have received most of the funds up to now: real estate, construction, transport, oil and gas, retail and supermarkets account for more than 60% of the total amount lent to Chinese firms to finance their projects (Figure 12.6). The total outstanding amount borrowed by Chinese firms via the syndicated loan market amounted to EUR 750 billion in 2021 (stock). Since China mainly relies on the domestic market, only 13% of its lending comes from abroad.

Figure 12.5: Household loans and NPISHs, % GDP



Source: BIS and JRC elaboration

Figure 12.6: Industrial sector funded by syndicated loans, % syndicated loans market in China



Source: Loan connector and JRC elaboration

12.3 High levels of lending by state-owned banks and non-performing assets

China's government is very involved in its banking sector and influences lending and deposit-taking activities. Since government initiatives offer high incentives for participation via funding, bank lending decisions may then appear as a policy tool reflecting government priorities (Allen et al. 2017; Turner et al. 2012). In addition, the largest Chinese banks tend to be government-owned and a significant (and disproportionate) share of bank credit in China is extended to SOEs and government infrastructure projects. According to public information (Orbis BankFocus), the global ultimate owner of the largest Chinese banks and of more than 60% of Chinese banks is the Chinese state[82].

However, strong interconnections between government and financial institutions can harm the stability of the banking sector (see Bisio 2020; IMF 2018, and IMF 2016a for further discussion), as government support in the form of liquidity may have uncertain effects. Government pressure to keep non-viable firms in operation rather than allowing them to fail provides low incentives for banks to favour well-performing and creditworthy firms in lending decisions (Kauko 2021; IMF 2016a).

Even if the 2021 statistics point to a decline in already low levels of non-performing loans (NPLs) to 1.7% of all outstanding loans[83] more than a year after the COVID-19 outbreak[84], S&P[85] estimated that there was a doubling in the NPLs from property/real estate loans up to 5.5% and that one third of real estate developers are assumed to be in financial trouble (Reuters 2021).

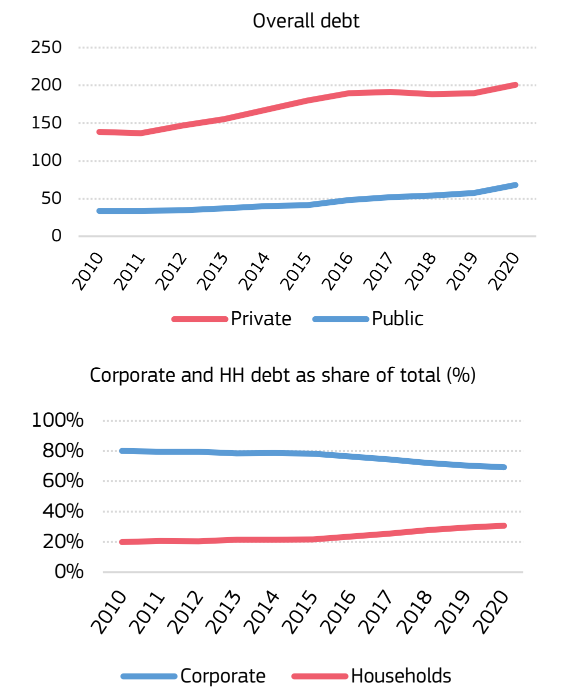
By April 2022, the People's Bank of China announced numerous policy measures intended to boost lending and support industries that have been hit by the COVID-19 pandemic and imposed lockdowns (see Bloomberg 2022). Most importantly, the bank promised to provide sufficient liquidity, which has to be seen in the context of prior measures such as the injection of gross liquidity via open market operations of about CNY 8 trillion (8% of GDP) from February to June 2020 (Funke & Tsnag, 2020). According to the IMF[86], the People's Bank of China established lending facilities of more than 2 trillion yuan (2% of GDP) to fund loans for small businesses, poverty alleviation and agricultural firms.

12.4 High credit to GDP ratio and increasing household indebtedness

China's credit boom has outpaced GDP growth raising vulnerability concerns, which in the event of financial disruptions and liquidity shortage can lead to a loss for the banking sector.

In fact, relying on bank loans has driven up private indebtedness (75% of the total debt in 2020) and fostered China's high level of corporate debt. This is the largest private debt segment overall, accounting for more than 65% of the total amount (see Figure 12.7)[87].

Figure 12.7: Chinese debt



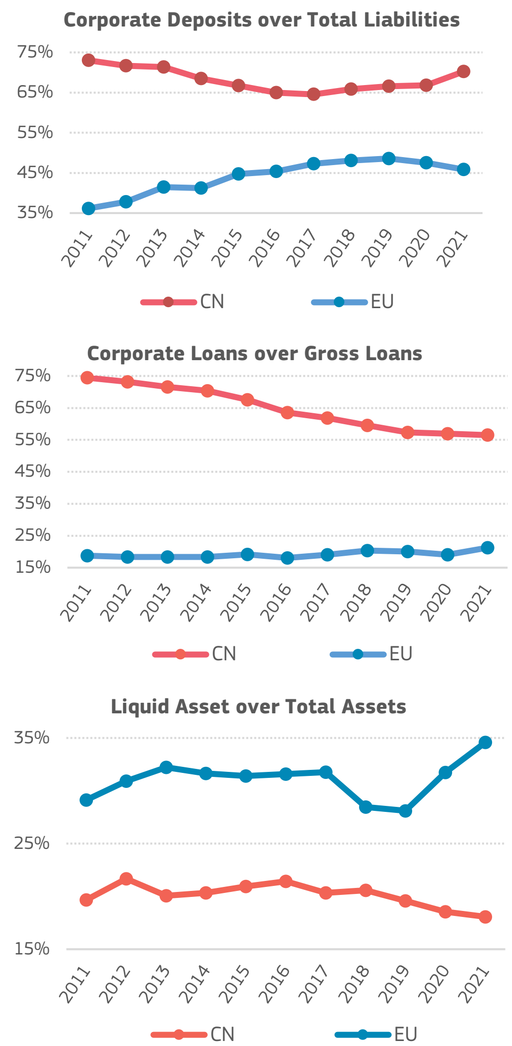
Source: IMF and JRC elaboration

Also, the increasing indebtedness of Chinese households has started to worry regulators, as this has become a source of concern for macro-prudential policy. Although the housing market and, in particular, the property developer crisis of 2021 appear to have been successfully averted, the elevated indebtedness of households may pose risks to economic and financial stability (see Apostolou et al., 2022). Despite ranking below the indebtedness of the corporate sector, regulators encouraged banks to strengthen practices for household debt, which has increased from 20% to 60% since the global financial crisis (see Figure 12.5) and which has now reached the same level as the euro area, yet ranking below the average in advanced economies (80%).

12.5 Chinese banks might be a source of liquidity risk

Chinese banks' business model might be a source of liquidity risks[88]. Chinese banks rely more heavily on deposits as a means of funding (corporate deposits as a share of total liabilities, Figure 12.8 top-left panel); make greater use of loans to finance firms (corporate loans as a share of total loans, Figure 12.8 top-right panel); and hold a more limited share of liquid assets (liquid assets as a share of total assets, Figure 12.8 bottom panel). Being much less equipped to pay debt obligations as soon as they become due, Chinese banks rely on state intervention to inject liquidity whenever necessary. Therefore maturity mismatches between assets and liabilities make it difficult for Chinese banks to hold large shares of assets that cannot easily be liquidated (IMF, 2018).

Figure 12.8: Aggregated indicators

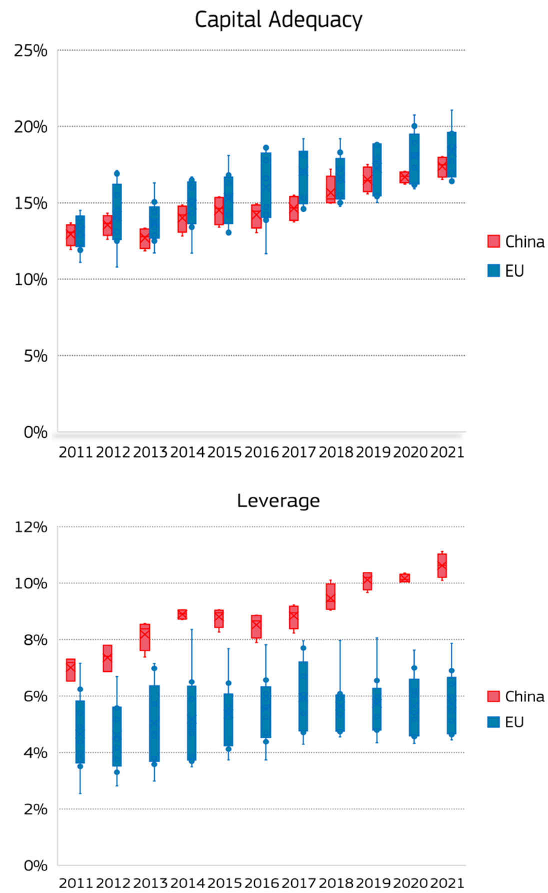


Source: ORBIS Bankfocus and JRC elaboration

This is particularly evident for global systemically important banks (GSIBs)[89]. Despite a stronger capital position in recent years (Figure 12.9)[90], they hold much lower buffers for cash flow shortfalls to satisfy liquidity needs in a timely manner under stressed conditions (Figure 12.10).

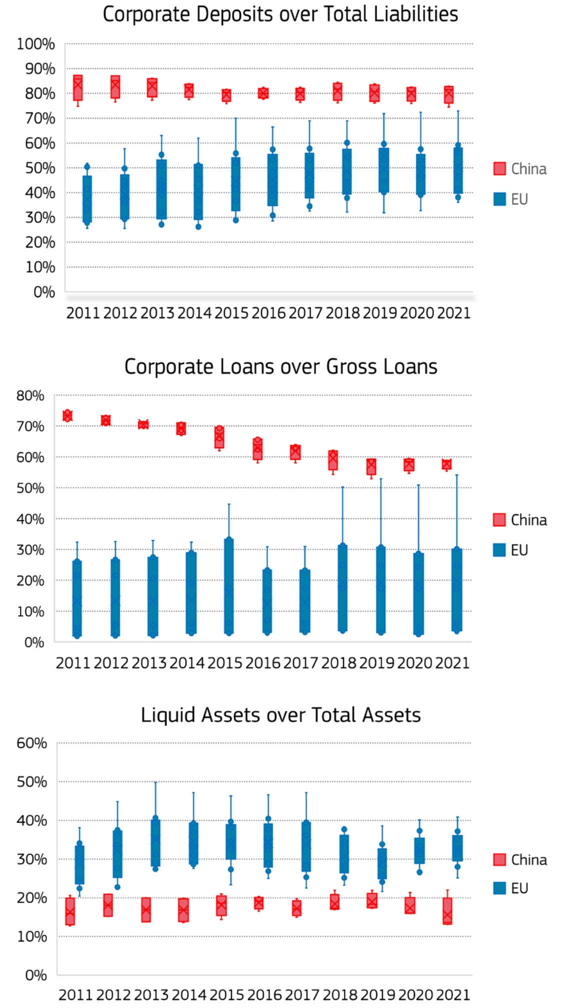
While commercial banks account for more than 80% of assets held by Chinese financial institutions and provided 68% of all credit in 2019, the seven largest Chinese banks[91] accounted for 47% of all commercial bank assets i.e. USD 15.9 trillion (Bisio, 2020, BIS, 2019)[92].

Figure 12.9: Capital adequacy ratios for GSIBs (Capital leverage ratios and Tier1 solvency)



Source: ORBIS Bankfocus and JRC elaboration

Figure 12.10: Business model indicators for GSIBs



Source: ORBIS BanksFocus and JRC elaboration

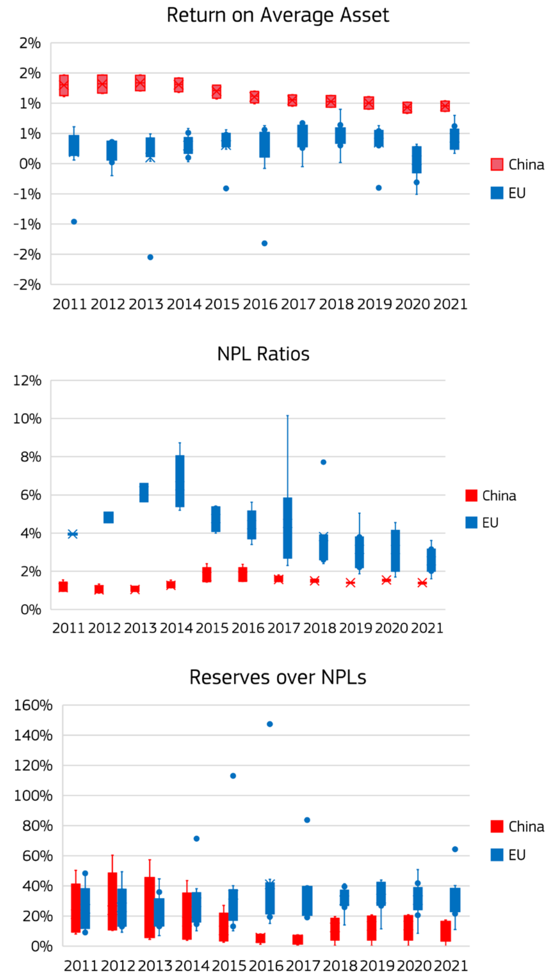
12.6 Chinese banks are not sufficiently diversified and post-COVID-19 profitability is under strong pressure

Chinese banks seem to lack investment alternatives and the limited development of the banking sector (domestic stock and bond market) has been compensated by the creation of non-bank financial institutions[93]. The US-China Economic and Security Review Commission (Bisio, 2020) defines the activity of commercial banks in China as 'little more than disguised bank lending'[94]. China is thus facing the risk of the absence of a financial system[95].

To make matters worse, funds are not always channelled where returns might be the highest, creating a capital misallocation. In addition, the Chinese business model previously discussed, combined with interest rate liberalisation, led to a reduction in the interest margin, pushing down profit levels.

Returns on assets of Chinese GSIBs have gradually declined in recent years (Figure 12.11), although they still outperform EU ones. This pressure on profitability has been amplified by the large amount in provisions held by Chinese banks to comply with the tight regulation of 150% minimum coverage ratios. While reserves are held to offset problematic financial conditions and cover for potential losses on impaired / NPLs, a large amount held in balance sheets negatively impacts banks' profitability.

Figure 12.11: Profitability, NPLs and reserve ratios for GSIBs (China and EU)



Source: ORBIS BanksFocus and JRC elaboration

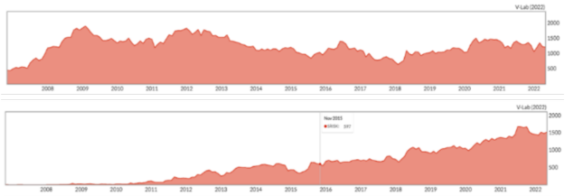
As firms have been significantly stressed by the pandemic, the share of bad loans is expected to increase regardless of the amount of NPLs already present (Figure 12.11). By

2021, regulators required banks to increase provisions to prevent pressure from bad loans. Even for banks less vulnerable to economic shocks, profitability might suffer a further reduction.

It is not clear how the Chinese banking system will perform in the aftermath of the pandemic, but this shock might complicate the overall profitability of banks. Behind the liquidity concern, an increase in the amount of bad loans[96] is likely to happen and expose financial institutions to severe consequences.

12.7 Chinese banks are rising in size and systemic importance

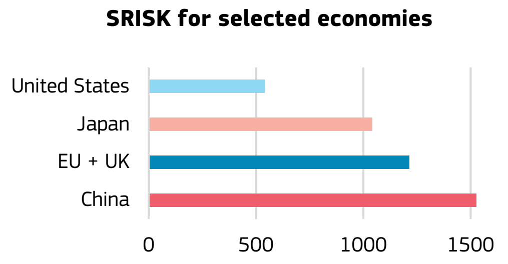
Figure 12.12: SRISK in US dollars for EU + UK (top panel) and China (bottom panel).



Source: The volatility Laboratory of NYU Stern Volatility and Risk Institute (https://vlab.stern.nyu.edu)

The systemic riskiness of China's banking system has increased over the past few years to a level similar to the peak of systemic riskiness of the EU and the UK during the global financial crisis. In 2021, China became the country contributing the most to the systemic risk of the global financial system (Figure 12.13). The SRISK systemic risk measure shows how the Chinese banking system might be vulnerable and under–capitalised, although state aid can be expected in case of turbulence. As the Chinese economy appears to be characterised by rising debt and deteriorating credit efficiency, the high score in the SRISK index raises concerns about financial stability. As financial stability between countries is interconnected, financial distress in China might spread to other economies and harm global financial stability, with the possibility of a crisis spreading to the rest of the world (Engle and Ruan, 2018).

Figure 12.13: SRISK – selected economies, 2022



Source: NYU Stern Volatility and Risk Institute

The size of China's financial system and the significant bank lending to state-owned enterprises could be a source of risk. Many of these loans are in fact non-performing, thus dragging down the valuation of bank stocks.

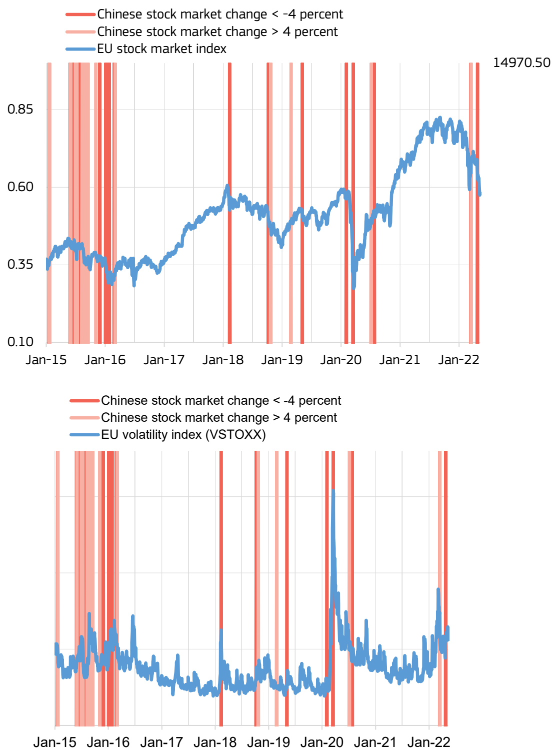
12.8 Strong financial spill-overs from equity and syndicated loans markets

In recent years, developments in the Chinese stock market played an increasingly important role for European financial markets. Determining the average impact is a challenging task, however more recent analyses (IMF 2016c) propose to pin down stock market changes of domestic origin in China which allows to relate those to US or European equity market returns and volatility.

Figure 12.14 highlights positive and negative changes (+/-4%) in Chinese stock market returns, which were not present in European or US financial markets the previous day (hence likely to be domestic in nature) and plots these against European market returns and volatility indexes. For instance, since 2015, there have been periods when substantial stock market declines in China spilled over to Europe in response to the introduction of regulatory measures, such as in 2016 or in summer 2021. In 2021, the Chinese government restricted certain business models and made regulatory decisions for some companies that lead to repercussions in China's tech company stocks. In addition, Chinese return spill-overs display increasing interconnectedness with measures of global uncertainty (e.g. volatility index – VIX), which in turn might affect European equity markets indirectly via an increase in global uncertainty.

Lending from Chinese banks to other countries might be an additional source of financial spill-overs. Despite the so far limited exposure of financial interconnectedness with the EU, there is the looming presence of Chinese banks as lenders. The syndicated loans market represents a unique opportunity to observe lending from Chinese banks to other countries.

Figure 12.14: EU market/volatility index vs Chinese stock market events

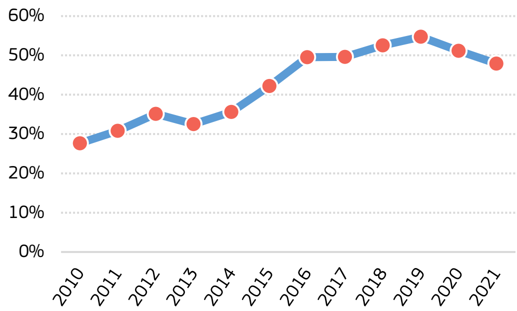


Source: JRC elaboration – Datastream

Public data show that the outstanding amount of loans lent by Chinese institutions totalled around EUR 1 billion in 2021 (stock). Figure 12.15 shows that the amount lent outside the country has increased since 2010 and is now comparable to total domestic lending. A share of 5% of this is directed to the EU to mainly finance financial services and the automotive and general manufacturing sectors in specific countries (Luxembourg, the Netherlands, Germany).

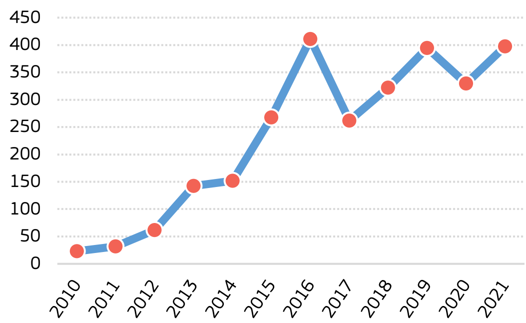
The presence of Chinese banks in the global syndicated loan markets has increased sharply compared to ten years ago, reflecting the increased international presence of Chinese firms. In 2021 alone, China participated in the syndicated market by offering around EUR 400 billion of new loans (Figure 12.16).

Figure 12.15: Share of non-domestic syndicated loans over total



Note: Outstanding Chinese sysndicated loans lent outiside the country
Source: Loan connector and JRC elaboration

Figure 12.16: China's syndicated loans (bn EUR)



Note: New CN syndicated loans each year
Source: Loan connector and JRC elaboration

12.9 Economic spill-overs potentially resulting in financial losses

Disruptions in key economic sectors in China could be an additional source of spill-overs to Europe. Shocks to the Chinese economy might negatively affect European companies, as reflected in strong trade linkages, which in turn could have an adverse impact on the European financial sector.

Key sectors in China comprise construction and manufacturing of textiles, machinery, vehicles and electrical and optical equipment. Even comparatively small shocks to these sectors can trigger strong propagation effects in other sectors and for China's trading partners. While shocks to the construction sector would primarily have implications to the rest of the

Chinese economy, second round effects in the Chinese economy could unfold in the rest of the world via reduced import demand. By contrast, shocks to some key manufacturing sectors would have a direct impact due to their role as an important intermediate input and final output supplier to European companies. In particular, sectoral shares of euro area bank loans to non-financial corporations indicate a substantial portfolio exposure to risks stemming from the manufacturing and the wholesale and retail trade sectors. Supply shocks from China could possibly put pressure on European manufacturing and wholesale trade, and hence the loans granted to these sectors (14% and 12% of total).

The EU economy is also exposed to Chinese import demand shocks that would result from geopolitical conflicts. Kireyev and Leonidov (2021) quantify the impact of a twin shock induced by a trade dispute between the US and China resulting in a reduction of exports to each other of around 5%. This initial shock might be at the expense of third parties such as the EU economy and could be amplified by important trading partners such as Italy and Germany in the EU, as well as Korea and Japan. While the overall effect on the EU of a continued trade war is expected to be contained, a recession in China might affect large parts of Asia, which in turn might result in a larger reduction of EU exports to the entire region.

All in all, the Chinese economy's growth has been remarkably resilient until 2019, reliably providing the world with goods and commodities. While the trade dispute between China and the US has shown limited effects on the EU economy, the COVID-19 pandemic and associated lockdown measures have uncovered vulnerabilities due to impaired supply chains for resources and goods, for instance in rare earth metals and semiconductors.

ENVIRONMENT AND ENERGY POLICY - KEY FINDINGS

China dominates wind energy investments and installed capacity, while market access for foreign firms is difficult. Rising demand for rare earths amplifies EU dependence on China, and circular economy practices in industrial parks cope with industry-led environmental challenges

In 2019, China led the world in cumulative installed wind energy capacity (338GW), followed by the EU (189GW) and the US (134GW). China also ranks first in cumulative installed offshore capacity (28GW), having surpassed the EU (16GW) and the UK (10GW).

Chinese investments in wind energy assets are triple those made by EU investors, while China and the EU refrain from investing in each other's wind technology. Chinese investments target the entire value chain including manufacturing plants, developers, stakes of energy utilities, entire wind farms or providers of AI-based systems. Investment targets are in most of the leading EU wind energy markets such as Belgium, Denmark, Germany, Spain and Ireland, and in smaller-sized or emerging markets such as Greece, Portugal and Sweden. Since the early 2000s, the EU and China have accounted for 31% and 6% respectively of new wind VC and private equity (VC/PE) global investments. Remarkably, neither has invested in the other.

China ranks first in wind energy filings, after overtaking the EU in 2009, patenting mostly in its home market, with only 2% of high-value inventions in 2016. The rate of (high-value) inventions shows that China has a limited stock of knowledge in wind energy compared to the EU. However, technological diffusion of EU knowledge stocks through trade has not occurred as China has protected its domestic market via direct financial incentives, local content requirements, VAT exemptions and import tariffs. The adverse business environment for foreign companies is worsened by a weak IP enforcement policy and a high number of infringements.

Higher demand for rare earth materials amplifies the EU's dependence on China, which has 30% of raw materials worldwide, and 40-50% of processed materials. China accounts for more than half the production of components and assemblies for solar panels, wind turbines and Li-ion battery production, with the exception of wind turbines manufacturing, for which the EU is in the lead. China has a particularly dominant role in the solar panels supply chain as the largest manufacturer of solar cells and modules since 2007, now accounting for 70% of their production worldwide.

Chinese industrial parks produce more than 60% of the national industrial output to support the circular economy. Chinese circular economy practices in waste and reuse take a holistic approach to align both the environment and development, and to cope with environmental challenges due to rapid industrialisation. China has created strong policies for a circular economy for almost twenty years now and has made considerable progress through regulatory measures and administrative guidance at the levels of provinces, cities and industries.

Since 2013, emission reduction measures targeting the concentration of PM2.5 demonstrate a move towards an air-quality-oriented strategy. Also, with its growing green energy sector, China is improving its air quality, especially in large cities. China owns half of the world's electric vehicles and the biggest share of electric buses and is now the second largest in renewable energy investment, accounting for 32% of global investment in 2018.

CIRCULAR ECONOMY IN CHINA AND IMPLICATIONS FOR THE EU

13.1 China's patterns of import dependence motivate a shift towards a circular economy

China's rapid economic development has required an increase in the demand for natural resources prior to any decoupling and saturation (Bleischwitz et al., 2018). Wang et al. (2020) demonstrate both the higher volumes in the use of metals, minerals, biomass and fossil fuels as well as the slow increase in the consumption of secondary materials in 2015 compared to 1995. There has been an increase in the domestic extraction of non-metallic minerals, as well as in the circularity rates[97], from 2.7 % to 5.8% for the input socio-economic cycling rates (ISCr), reflecting the increasing share of secondary materials. An increase in circularity for the output socio-economic cycling rates[98] (OSCr) from 7.2 % to 17 %, reflects instead progress in the management of industrial solid waste.

As Figure 13.1 illustrates, China has become the world leader in importing commodities, with a market value of USD 801 billion, which makes it vulnerable to price changes and supply chain disruptions. The volume of Chinese commodity imports increased by a factor of ten between 2000 and 2018, with the most significant increases in forestry products and minerals and metals. Furthermore, China's share of international commodity markets grew consistently from the 1990s, when it was only 3.8 %, to 18 % in 2018. By comparison, the EU's share remained rather stable throughout this time (Chatham House Resource Trade Database, 2018).

China has a negative commodity trade balance with the EU. The EU exports, in particular, forestry products, metal products and agricultural goods on a large scale to China the value of EU exports in 2019 was around USD 29 billion, while the value of imports from China was around USD 16 billion. Both the value and the quantity of metal exports from China to the EU have been decreasing since 2008. They reached their lowest point in 2015 and have been increasing moderately since then, with steeper increases for cobalt, zirconium and titanium (Chatham House Resource Trade Database, 2019).

Resource productivity has almost tripled in China since the 1990s, mainly driven by the need for a response to pressing domestic environmental challenges (e.g. urban air pollution and waste, water pollution) and a strong resource import dependence in China's role as a manufacturing hub of the world economy. Conversely, resource productivity has remained almost unchanged in the EU. This may be due to a successful industrial policy driving a decoupling of GDP growth from inputs of materials in manufacturing, at a time when China has become the manufacturing hub of the world and parts of Europe started to deindustrialise.

13.2 China's circular economy as a holistic approach to the environmental challenges stemming from rapid industrialisation

China has had strong policies towards a circular economy in place for almost twenty years. It has made considerable progress towards this goal through regulatory measures and administrative guidance at the levels of provinces, cities and industries.

China introduced the concept of circular economy in 2002 after several years of economic growth. In 2005 a policy framework, main objectives and principles, key tasks and policy measures set the ground for creating a circular economy in China within the Five-Year Plans from 2006. By comparison, the EU had a strong uptake only in 2015 with the adoption of the 2nd Circular Economy package.

In China, a Promotion Law (2008, updated in 2018) requires any new industrial policy to meet circular economy principles. Furthermore, in 2012 the 18th Chinese Communist Party National Congress introduced a new strategic goal by considering a fully-fledged resource recycling system as one of the goals of building a moderately prosperous society.

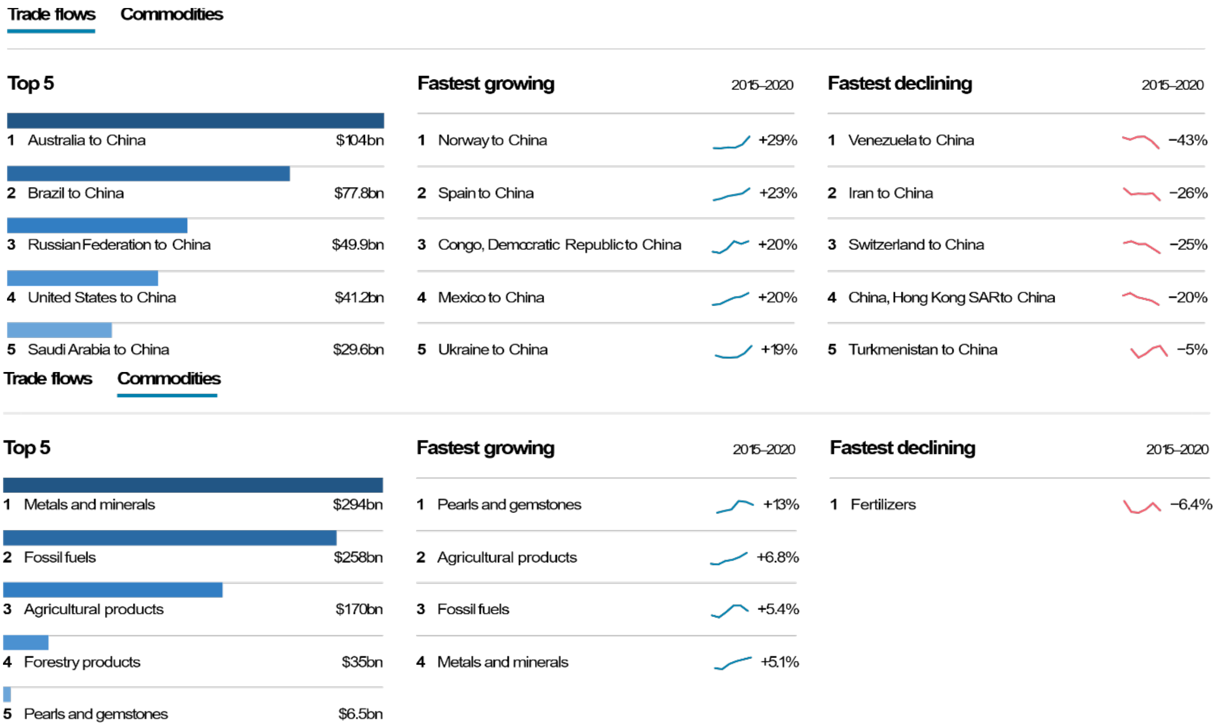
More recently, the General Department of the State Council's Opinions on Accelerating the Development of Circulation and Promoting Commercial Consumption (2019) propose the development of 'Internet plus Circular Economy'[99], which has also promoted investment, financing, services and cooperation in the circular economy. In addition, China is looking at an 'integration of two networks', which will promote urban innovation systems, the recovery of renewable resources and domestic waste sorting and logistics.

13.3 China's ambitions for an 'ecological civilisation' are supported by circular economy indicators

China places a great deal of emphasis on supply chains, scale and location for its circular economy ambitions (McDowall et al. 2017). The country has been developing circular economy indicators at different levels macro, meso and micro - which it calls 'three plus one'. The macro level addresses the macro cycles in society (including provinces), the meso level concerns meso cycles in industrial parks, and the micro level applies to micro cycles in businesses. "'One' involves waste treatment and resource recovery by the waste industry. The indicators are based on the material flow analysis method, which consists of three interconnected categories[100] to deliver a comprehensive picture of the status of the circular economy in China.

What is currently lacking are indicators that make it possible to track continuous progress in achieving a circular economy in China; e.g. resource productivity is often in policy documents but still lacks a standardised accounting method in China (Wang et al. 2020). Such core indicators also permit scenario simulations to be made and make it possible to model the impact of the circular economy at the country and sector levels.

Figure 13.1: China as the world's largest commodity importer 2018



Source: Chatham House Resource Trade Database

13.4 Industrial supply chains and eco-industrial parks as a basis for decoupling GDP from resource use in China

China's economic model places a great deal of emphasis on eco-industrial parks (EIPs) as demonstrators and upscaling mechanisms (Mathews and Hao Tan 2016). In the 1980s, the Chinese government started setting up industrial parks in coastal cities. China was estimated to have 2 543 parks in 2019 (World Bank, 2019) that produced more than 60% of national industrial output. While many of those traditional parks are seen as environmentally harmful (Fan et al. 2017; Bai et al. 2014), China has also been establishing EIPs since 2001, in collaboration with the United Nations Environment Programme (UNEP) as a tool to combine industrial innovation and development towards what is now referred to as an ecological civilisation. In the future, both types of parks are likely to play a vital role in circular cities and for a better circular economy overall. Even though EIPs have been set up in most parts of the world (UNIDO, 2016), China is clearly ahead in having implemented these initiatives at such a rapid pace and on such a large scale (Liu & Cote, 2017).

The National Demonstration EIPs (NDEIPs) programme has a concise set of indicators and performance targets, strong government support and direct involvement, and strict regulation (Bai et al. 2014; Huang et al. 2019; Hong & Gasparatos, 2020). By 2020, more than 90 industrial parks had been included in the NDEIPs, mainly located in the more developed coastal regions. These NDEIPs focus on the manufacturing industry[101], including e.g. electronics and information technology, equipment and biological medicines.

New EIP standards (HJ/T274-2015) have been implemented since 2016. However, despite a system of comprehensive indicators at various levels in China, there is lack of clarity about core indicators or key performance indicators. The main groups of indicators are shown in Table 13.1.

Industrial supply chains are at the heart of China's economic development. Establishing EIPs on a large scale and transforming existing industrial parks can be seen as a basis for the decoupling of GDP from resource use in China. During the 12th Five-Year Plan (2011-2015), the energy consumption per unit of value added of the non-ferrous metals industry (above a designated size) was cut by 22%, i.e. there was a relative decoupling of GDP from industrial energy use.

During the 13th Five-Year Plan (2016–2020), China addressed green manufacturing and the non-ferrous metal industry through a number of pilot and demonstration projects to promote the application of energy conservation, emissions reduction and low-carbon technologies and products. The circular economy has also been promoted through technical measures promoting remanufacturing, industrial recycling and industrial symbiosis (see also Table 13.1). Furthermore, IT and 'urban mining' have been introduced to encourage the recycling, sorting, and reduction of impurities and toxic elements. There is large-scale use of high-alumina coal ash resources and various attempts to control heavy metal pollution.

China has proposed development targets for the period of the 14th Five-Year Plan (2021–2025) and the long-term goal of 2035, which emphasises overall improvements in the efficient use of resources for materials.

However, given China's impressive speed of development, technological innovation, and success in relative decoupling, there is both the opportunity for a leapfrogging and the risk of being stuck in a bottleneck in the years ahead. Critical issues in both cases are policy coordination and system integration in China. While some reports paint a bright picture of future opportunities (e.g. Energy Transition Commission 2019, Ellen MacArthur Foundation 2018), there are possible nuances and challenges with respect to:

Regional differences: there are considerable differences between China's provinces, as illustrated by metals production. The numerous EIPs are primarily located in the eastern provinces and are spurring impressive large-scale changes. However, western and northern provinces do not have the institutional capabilities to absorb innovations. Therefore, better policy coordination and learning between provinces and institutional reforms to reach the defined goals will need to be addressed.

Differences by sector: High-tech and export-oriented manufacturing sectors are highly advanced and greening their supply chains, while sectors like construction, agriculture and others are lagging behind. China will have to improve in design, cross-sectoral technology absorption, and refurbishment beyond technological innovations, where it excels, and applying disruptive transformations such as for e-vehicles, IT and AI. China does not have an accessible systemic innovation scoreboard comparable to the EU's Community Innovation Survey (CIS). There is therefore scope to develop an evidence base in China for cross-sectoral analysis and learning.

Table 13.1: Evaluation indicators for National Eco-industrial Parks (HJ/T274-2015)

Groups	No.	Indicators	Units	Standard	Remarks
Economic development	1	**The proportion of high tech enterprises output value of gross industrial output value**	%	**≥ 30**	At least one indicator the standard
	2	Industrial added value per capita	10^4¥/Person	≥ 15	
	3	**The average three-year growth rate of industrial added value**	%	**≥ 15**	
	4	**The proportion of remanufacturing industry added value of the gross industrial added value**	%	**≥ 30**	
Industrial Symbiosis	5	**The added eco-industrial chain numbers after enforcing EIP demonstration program**	Unit	**≥ 6**	Required
	6	Comprehensive utilization rate of industrial solid waste	%	≥ 70	At least one indicator the standard
	7	**Usage rate of renewable resources**	%	**≥ 80**	
Resource conservation	8	**Industrial added value per unit industrial land area**	Hundred million/ Square kilometers	≥ 9	At least one indicator the standard
	9	**The average three-year annual growth rate of industrial added value per unit industrial land area**	%	≥ 6	
	10	**Elastic coefficient of comprehensive energy consumption**	-	-When annual growth rate of industrial added value in the EIP demonstration period is > 0: the value must be ≤ 0.6; -When annual growth rate of industrial added value in the EIP demonstration period is < 0: the value must be ≥ 0.6	Required
	11	Energy consumption per unit of industrial added value	Metric ton of standard coal/ 10^4 RMB	≤ 0.5	
	12	**Application ratio of Renewable energy**	%	**≥ 9**	
	13	**Elastic coefficient of fresh water consumption**		-When annual growth rate of industrial added value in the EIP demonstration period is > 0: ≤ 0.55; -When annual growth rate of industrial added value in the EIP demonstration period is < 0: ≥ 0.55	
	14	Fresh water consumption per unit industrial added value	m3/ 10^4RMB	≤ 8	At least one indicator the standard
	15	Recycling rate of industrial water	%	≥ 75	
	16	Reuse rate of reclaimed water	%	-Water deficient cities > 20%; -Jing-Jin-J i areas > 30%; -Other areas > 10%	
Environmental protection	17	Rate of reaching the discharging standard for key pollution sources	%	Meet the standard	Required
	18	The condi tions of national and local key pollutant emissions		Meet the standard	Required
	19	Frequency of severe environmental accidents		0	Required
	20	Completion degree of Environmental management strategies	%	100	Required
	21	Implementation rate of key enterprises' Clean production audit system	%	100	Required
	22	Centralized sewage treatment facilities	%	Exist	Required
	23	The completion rate of environmental risk prevention and control system	%	100	Required
	24	Utilization rate of industrial solid waste (including hazardous wastes)	%	100	Required
	25	Elastic coefficient of main pollutant emissions		-When annual growth rate of industrial added value in the EIP demonstration period is > 0: the value must be 0.3; -When annual growth rate of industrial added value in the construction period is < 0: the value must be 2:0.3	Required
	26	The annual reduction rate of carbon dioxide emissions per unit industrial added value	%	≥ 3	Required
	27	Waste water emission per unit industrial added value	T/ 10^4RMB	≤ 7	At least one indicator the standard
	28	Solid waste discharge per unit industrial added value	T/ 10^4RMB	≤ 0.1	
	29	Green cover percentage	%	≥ 15	Required

Source: Huang et al. 2019

The growing middle class and consumerism: China is facing growing challenges related to packaging, textiles, mobility, tourism, and food waste. Given that most circular economy policies have a focus on industrial supply (i.e. on resource efficiency), there is a need to shape the emerging consumer goods industries and address the full life cycle with users and end-of-life patterns. In addition to better policies, design and new business models may help as well as data to underpin evidence.

What direction for the Belt and Road Initiative (BRI)? China's Belt and Road Initiative seeks to connect Asia with Africa and Europe via land and maritime networks to improve regional integration, increase trade and stimulate economic growth. Its investments focus on infrastructure and are intended to achieve positive effects in all the countries involved. By allowing for mutual benefits for China and its partners, the BRI is also expected to contribute developing markets for Chinese products in the long term and reduce industrial excess capacity in the short term. Since 2016, China's state-led BRI lending volumes have been decreasing. The BRI appears to have shifted its focus to 'high-quality investment', including through a more extensive use of project finance, risk mitigation tools, and green finance (EBRD, 2019). The early years of the BRI resulted in a lifeline for Chinese 'zombie' industries (i.e. resource-intensive industries that it was crucial to develop but are now regarded as 'stiff but deathless'), with negative environmental effects at local level. A greening of the BRI platform[102] has been set up but proper assessment criteria have not yet been established for infrastructure investments and to implement solutions with partner countries. Given the scale of the BRI, this is of pivotal importance for both a circular economy and decarbonisation pathways internationally.

China's industrial recovery post-COVID-19 has led the demand for materials and electricity and the rising needs for coal. Additional demand for resource-intensive industries stemming from the BRI adds to these challenges as they provide short term solutions for overcapacity in provinces but create local environmental pressures (Tian Zhu et al. 2019). Evidence from the Financial Times (2020) suggests that China is now producing nearly 60% of the world's steel, aluminium and cement, and might even increase coal production. This is quite in contrast to China's recent pledges on decarbonisation and to the decline in coal use around the world. Despite the achievements in decoupling GDP from the use of resources in recent decades and ambitious pledges for the future, China's industrial policy will be stretched in terms of cohesion across provinces. Potentially disruptive institutional reforms may need to be introduced.

13.5 Opportunities for EU-China cooperation for a circular economy

Despite certain barriers and challenges, the EU and others can draw useful lessons from China, especially on their upscaling efforts and industrial strategy. A combination of ambitious policy goals, standards, financing, and quick decisions on large scale implementation have led to a doubling in resource productivity, with a focus on manufacturing. There is now a policy learning opportunity from the EU and China collaborating on:

a) New core indicators for a circular economy and monitoring framework at different levels, including Member State and regional developments, industry and business, and at the local level. It would be useful to have a common accounting framework for publicly listed companies and reporting on annual progress and on gaps between targets and current resource use. Comparing existing data sets and exploring how a community innovation survey and circular economy / resource efficiency scoreboard approach could be set up and accessed in China could be invaluable for evidence-based evaluations and foresight processes.

b) Standards for product design and market development for new products, including RFID[103] codes for tracking and monitoring of material flows. This would need a policy forum with industry experts to take it further and agree on pilot products, which could possibly be selected from resource-intensive consumer goods that have relevant parts of their supply chains in China. These efforts should address carbon footprints and the circular economy, taking advantage of new core indicators (see previous point) and ongoing ISO[104] efforts.

c) The urban circular economy and synergies with industry symbiosis, including construction and demolition waste, water and waste-water management, food and food waste and the supporting role of start-ups. The recent initiative for a New European Bauhaus and other efforts (OECD 2020b) could help set up city partnerships and align efforts around multi-level governance and the dissemination of technology. This could also become an opportunity to address consumption patterns, strengthen extended producer responsibility (EPR) stewardship and establish databases on building stocks and relevant material flows.

All three areas will need inputs from and alignment with key industrial sectors such as metals, construction, electronics, automotive, chemistry/plastics, textiles and fashion, food, packaging, and logistics and actions to green supply chains across borders and towards ensuring EPR.

Given the 2018 memorandum of understanding between China and the EU on progress for a circular economy the high-level policy dialogue could become a reality. There is scope for working groups to align databases, evidence cases, and build trust into future steps of collaboration. With support from Horizon Europe Framework Research and Innovation Programme and other existing mechanisms such as Switch Asia, a policy dialogue could establish and strengthen a platform and also discuss targets and roadmaps, and collaborate on modelling to measure socio-economic and environmental impacts. The new geopolitical context and the EU's open strategic autonomy objectives[105] point towards common interests in the green transition and opportunities for mutual benefits. More efforts in the EU and China will be needed to align circular economy goals with the recent pledges to reach net zero carbon by 2050 in Europe and 2060 in China. A strengthened partnership between the EU and China on the circular economy is an opportunity to help achieve these goals.

AIR QUALITY IN CHINA

14.1 Decoupling economic growth and air pollution are focal points of China's goal of an ecological civilisation

China alone is expected to be responsible for one third of the predicted doubling of the world's urban population between 1990 and 2025, a rapid and widespread phenomenon which is subject to limited control (Guinot, 2008). As a result, the natural resources that China's growing urban areas need to function have been under increased pressure. Authorities have faced the urgent challenge of reducing air pollutant emissions[106] coupled with growing urban populations, living standards and energy consumption.

The initially low level of urbanisation compared to already developed countries led to the significant expansion of existing large urban centres and a higher exposure to the health risks associated with pollution, especially for particulate matter (PM).

14.2 Industrial and residential emissions are the major contributors to China's particulate matter concentrations due to coal and biomass burning

Secondary PM (26-33% of particulate matter), coal (7-29%), dust (9-23 %), vehicle exhaust gases (3-26 %), industrial emissions (6-28%) and biomass combustion (6-13%) contribute significantly to PM2.5[107] concentrations in Beijing (Miller and Xu, 2018; Zhang and Cao, 2015).

Looking at the mortality caused by air pollution by sector of activity (Gu et al., 2018), the residential sector (heating and air conditioning) and industry are clearly dominant in the most populous provinces of eastern China, while agriculture and natural particles, in particular from deserts, play a bigger role in the West of China and the Tibetan Plateau.

Desert areas over western and northern China create major dust events in its cities. Particles of desert origin can move long distances from the emission zones and have an impact on people in cities. Beijing, for example, is particularly affected by mineral dust from the Gobi desert (Wang et al., 2017). High concentrations of PM in Beijing and Shanghai are indeed related to the intensity of these phenomena (Bessagnet et al., 2017).

14.3 Stringent and efficient emission reduction measures improve air quality in China, particularly in large cities

To reduce high levels of air pollution and mitigate adverse health effects, the Chinese Council of State published an action plan for air pollution prevention and control in 2013, which includes ten specific measures and target limit values to be achieved. The level of emissions' has decreased year on year and air quality improved considerably. In fact, the annual average concentrations of SO_2, NO_2 and PM10 dropped by 93%, 38% and 55% respectively between 1998 and 2017 in Beijing (UN Environment, 2019). To tackle air pollution, Beijing also launched in stages extensive programmes for all sectors of activity, particularly energy production and road traffic (Figure 14.1).

14.4 Despite improvements, air quality in China is still lower than in the EU and US

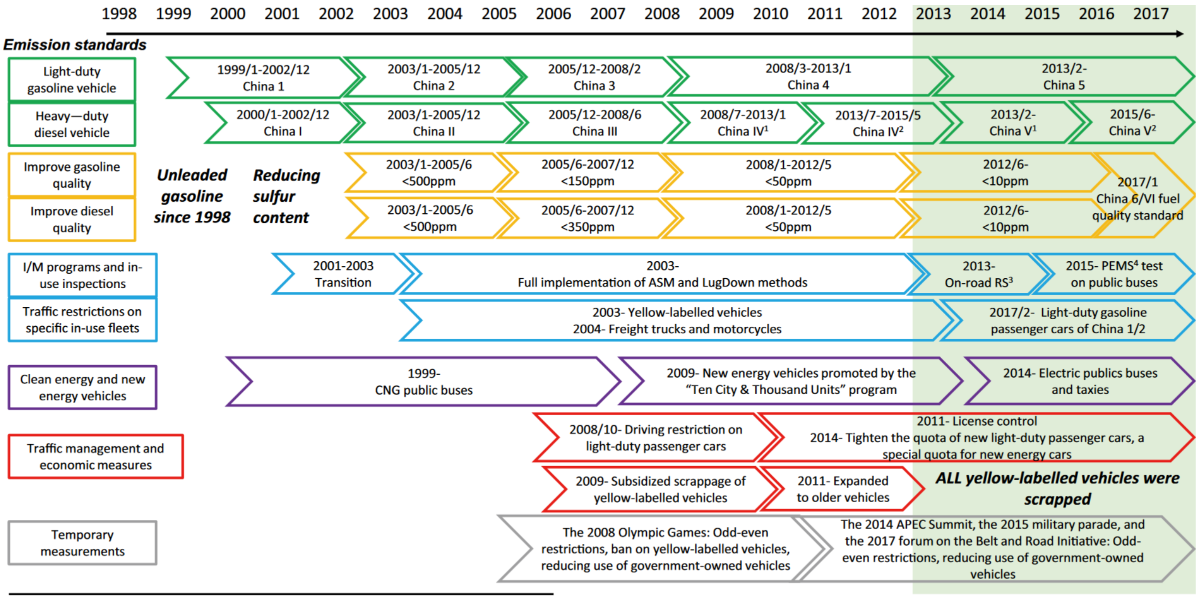
The concentrations of PM2.5 in China deteriorated until 2012-2013, but showed a clear improvement between 2013 and 2019. The population-weighted values of PM2.5 fell by 25% (HEI, 2020) compared to a decrease of 12% in western Europe. However, age-standardised deaths per 100 000 people attributable to PM2.5 in China did not follow the same trend (Figure 14.2).

Surface O_3 concentrations have still been increasing in urban areas across China (Liu and Wang, 2020)[108]. The causes vary between cities, such as NOx and PM in Beijing, NOx and VOC in Shanghai, NOx in Guangzhou, and PM and SO_2 in Chengdu.

These results show how PM2.5 concentrations are driven more by residential and industrial emissions than road traffic emissions in China. The nationwide urban-to-rural population migration, coupled with the fall in backward migration due to the quarantine, increased the population-weighted exposure (Shen et al., 2021). This increased household energy consumption as well as the share of individuals exposed to rural household indoor air pollution.

The link between environmental issues and the

Figure 14.1: Main measures to reduce road traffic emissions in Beijing



1. Only implemented for public fleets; 2 for freight trucks and long-distance coaches; 3 remote sensing test; 4 portable emission measurement system

Source: Reproduced from UN Environment (2019)

14.5 COVID-19 lockdowns improved air quality in China but may have led to higher exposure to indoor air pollutants

The COVID-19 pandemic led to measures restricting mobility to curb the spread of the virus. China was the first to adopt such measures in the epicentre of the pandemic in Wuhan in January 2020, followed by other Asian countries and the rest of the world in March. These measures clearly affected the level of air pollution with a fall of NO_2 concentrations in urban areas of up to 50% observed throughout the world (Gkatzelis et al. 2021). The decrease in PM concentrations was slightly higher in China than in the EU (Figure 14.3).

ongoing upheaval in China's economy is challenged by an ageing population and higher risk exposure for vulnerable subjects. The increasing health costs for society exert continuous pressure on the Chinese authorities to take the necessary measures. The environment, and air quality in particular, is becoming an important component of urban management.

14.6 Future research on micro sensors and artificial intelligence could lead to better assessments of air policy strategies

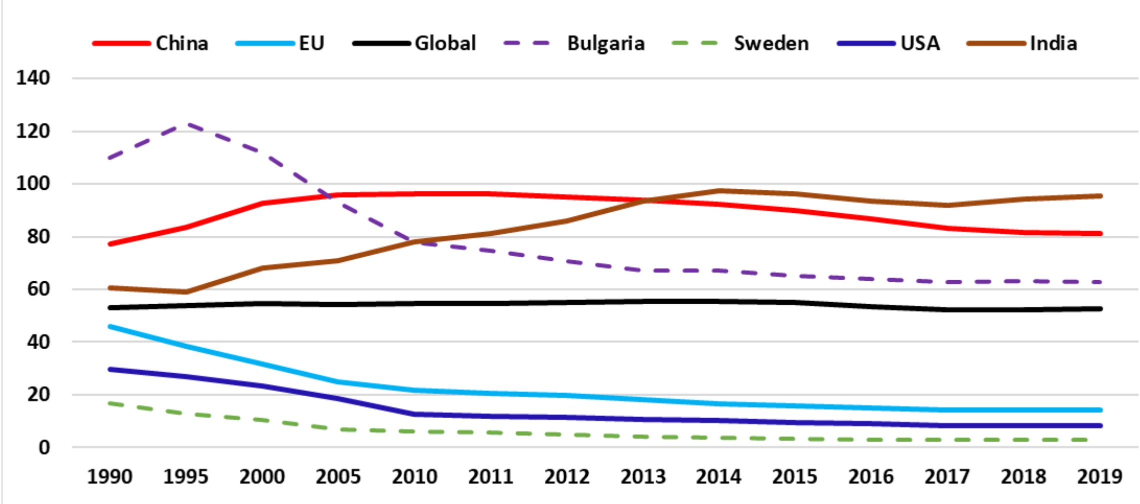
Recent literature confirms the association between exposure to PM2.5 and adverse health effects, including cardiovascular, and respiratory mortality, hypertension, lung cancer, chronic obstructive pulmonary disease, influenza (Miller and Xu, 2018) and, more recently, the COVID-19 (Connerton et al., 2020; Solimini et al., 2021).

The stringent control of air pollution in China since 2013 has led to a sharp decrease in PM2.5, while O_3 concentrations have remained at high levels and are increasing. The effect of PM on O_3 chemistry (Li et al., 2019) spurred the scientific community and government authorities to propose more sophisticated emission reduction strategies to lower both PM and O_3 concentrations.

The use of electric vehicles should be accompanied by measures to contain air pollutant emissions generated by battery power in countries such as China, where electricity is still largely produced by fossil fuels that can generate greenhouse gas emissions and pollutants (Chen et al., 2018).

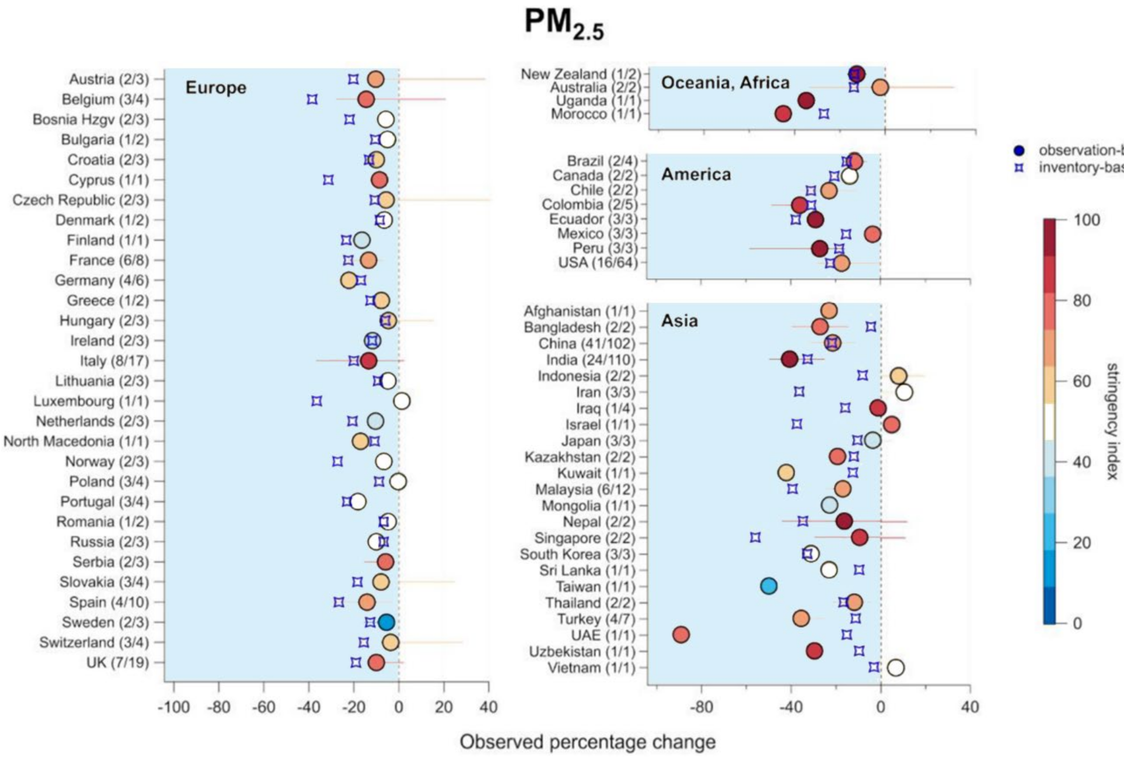
With its growing green energy sector, China is becoming a leader in tackling the increase in greenhouse gas emissions. The country already owns half of the world's electric vehicles and the biggest share of electric buses. China is now the second largest country in terms of renewable energy investment, accounting for 32% of 2018 global investment, followed by Europe and the US with 21% and 17%. Since 2013, controls on multiple sectors have targeted the concentration of PM2.5, marking a transition to a strategy oriented to improving air quality.

Figure 14.2: Age-standardized deaths/100,000 from PM2.5 over 1990-2019



Source: HEI, 2020

Figure 14.3: Median percentage decrease in PM2.5 (circle markers)



Note: Error bars: 25th and 75th percentiles of the distribution. Colour intensity: median stringency index based on all measurements associated with each country. Numbers in parentheses: number of publications and of data sets collected at each region/continent

Source: Gkatzelis et al., 2021

WIND ENERGY

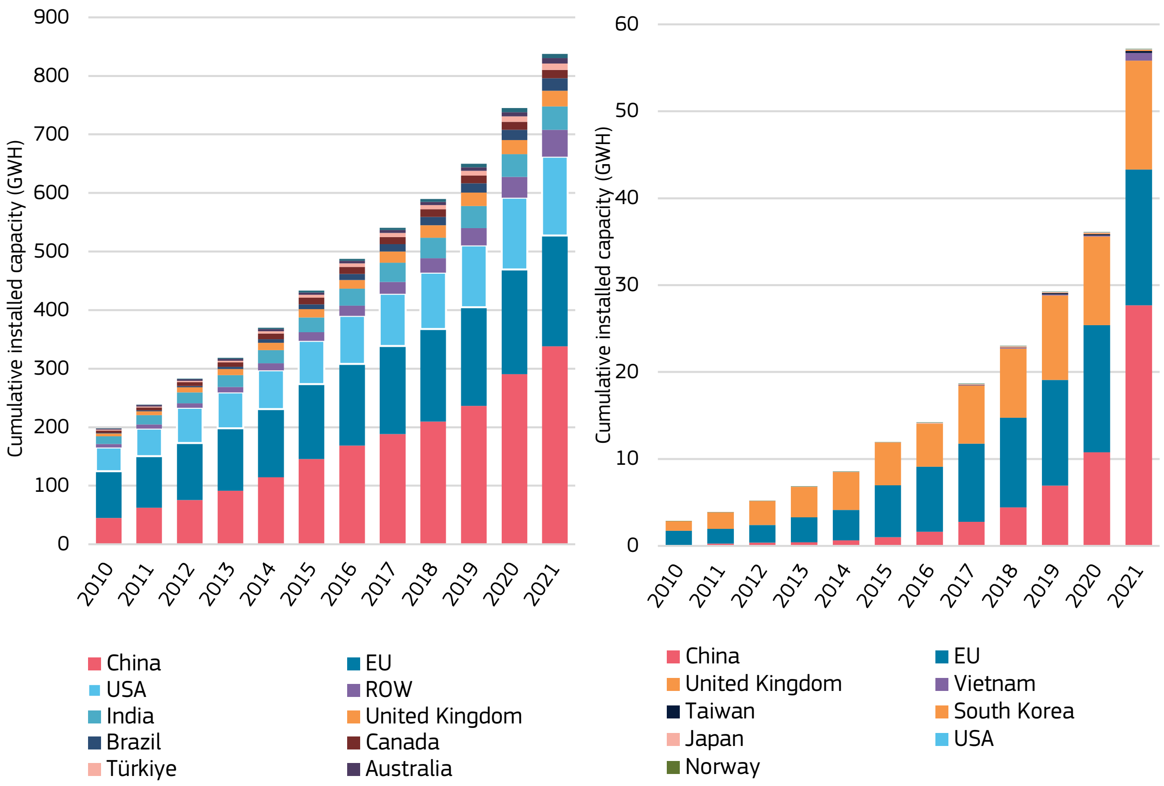
15.1 In 2021, China led globally with 338GW of cumulative installed wind energy capacity, but stood at a crossroads to a post-subsidy era

The wind energy sector is key to China's ambition to reach climate neutrality before 2060 (FMPRC, 2020). 2019 estimates of wind capacity investment in China were at an all-time high of around EUR 49 billion, of which EUR 13 billion was offshore (Frankfurt School-UNEP Centre/BNEF 2020). China leads the world in cumulative installed capacity, amounting to 338 gigawatts (GW) in 2021, with the EU at 189GW and the US at 134GW. (GWEC, 2020a; JRC, 2020). China now ranks first in cumulative installed offshore capacity (28GW), having surpassed the EU (16GW) and the UK (10GW) (Figure 15.1). This latest surge in Chinese wind deployment can be explained by a set of new policies targeting renewable energy integration and a shift since 2018 from feed-in tariffs to a tender-based support scheme.

The Chinese government announced that subsidies for offshore wind would end from 2022 onwards, however support schemes at provincial level can continue. Moreover, China provides incentives and targets actions on the regions with the best resource potential and higher energy demand. For example, since May 2019 a mandatory mechanism is in place to ensure an increase in renewable energy consumption in provinces via a quota system (NDRC/CNREC 2020).

Import restrictions on bearing and blade materials from Europe and Ecuador due to COVID-19 have delayed the construction of offshore projects, forcing the Chinese offshore wind industry to request an extension to the deadline for grid connections. Nevertheless, the

Figure 15.1: Global cumulative installed capacity of onshore wind (left) and offshore wind (right)



Source: JRC based on GWEC (GWEC 2022, JRC 2020) expected annual deployment rate is in line with current and future grid connection targets for China's coastal provinces (GWEC 2020b).

15.2 In 2019, EU companies accounted for only 2.5% of new capacity installed in China, but the growing offshore sector will provide opportunities to enter the market

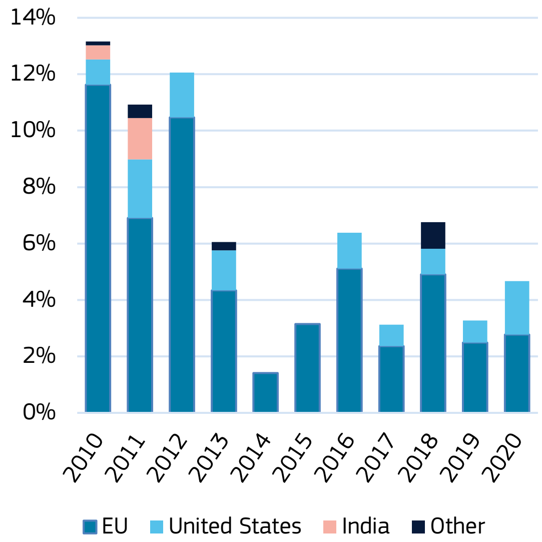
Chinese manufacturers have strongly consolidated their share of the home market. Since 2013, the penetration of foreign manufacturers has been below 7% of installed new capacity, down from 13% in 2010[109]. However, the EU's small share of installed capacity is expected to have increased in 2020, as EU companies secured 1.5GW of onshore wind orders to be delivered by the end of that year (WPM, 2019a; 2020a).

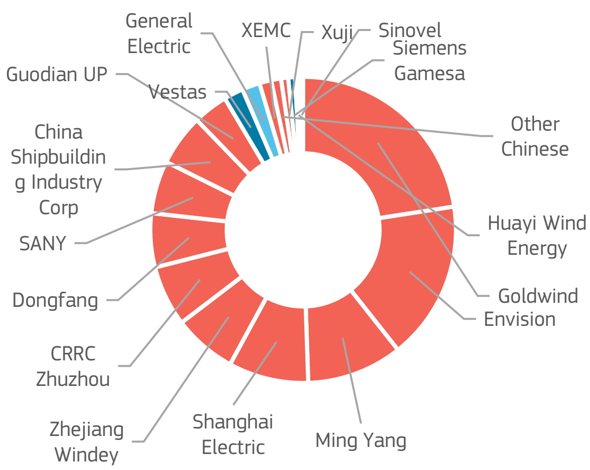
EU turbine manufacturers still seem to lead in terms of quality and technological development. However, Chinese companies are quickly improving, in particular those manufacturing key turbine components. Today, western turbines contain some key components made in China, either by Chinese or western manufacturers. Depending on the market supplied, the ratio of Chinese to western components can vary from zero in the case of Enercon to nearly 90% in the case of General Electric turbines certified for the Indian market[110]. Chinese manufacturers (particularly Shanghai Electric, Envision, Goldwind and Mingyang) also dominate the Chinese offshore wind market. (CWEA/GWEC/SEWPG, 2020).

Partnerships with local wind developers are a prerequisite for foreign companies entering the Chinese market. The market is dominated by state-owned power utilities and energy companies (Figure 15.2). So far, foreign investments are rare and often short-lived (Energy Iceberg 2020b)[111]. This could change in view of the expected growth in offshore wind and China's nascent offshore wind supply chain. Two European project developers have recently entered the Chinese offshore wind market (Equinor in 2019 and EDF in 2020), with other major foreign offshore manufacturers developing their capabilities in this area.

Despite China's significant market size, offshore wind developments are under threat from tensions in provinces adjacent to the South China Sea (Energy Iceberg, 2020c). Cooperation in the offshore installer market might be pivotal for the Chinese offshore wind market, as the availability and capabilities of installation vessels do not match current deployment plans[112]. Although around 39% of the world's heavy-lift and jack-up vessels are located in China, and Chinese companies have increased their capabilities - the vessel fleet has increased by a factor six since 2015 (WPM, 2019b) - a lack of experience in installing offshore wind projects provides the opportunity for foreign subcontractors to enter the market (Energy Iceberg, 2019).

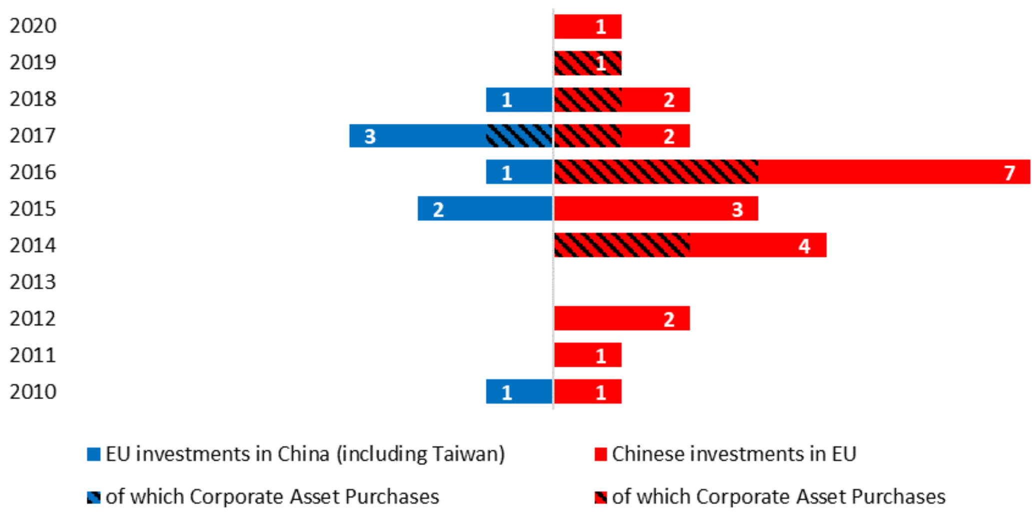
Figure 15.2: Market shares and origin of wind of foreign OEMs in the Chinese wind energy market over 2010 - 2020 (left) and distribution of market shares by OEMs in 2019 (right)





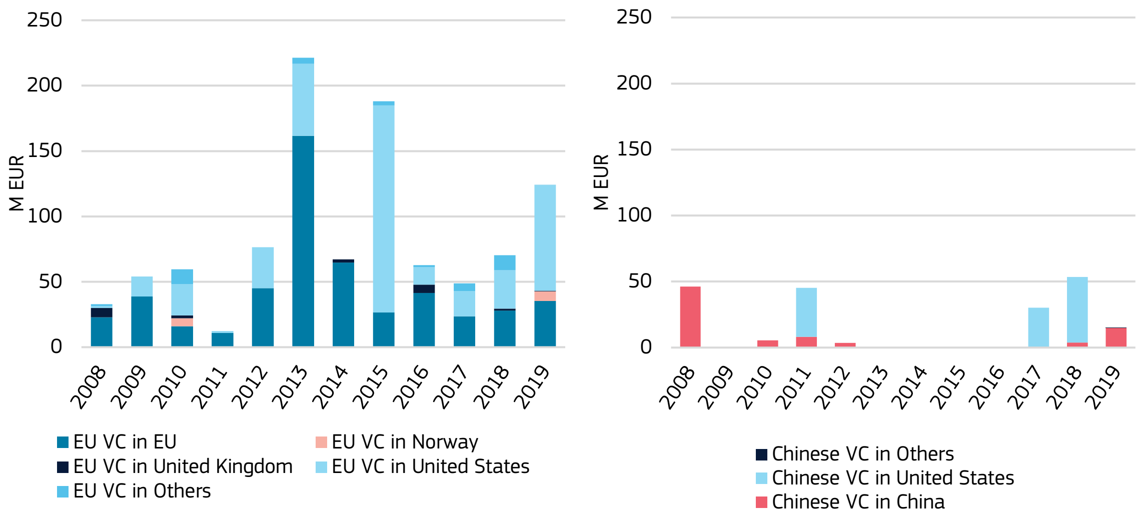
Source: JRC analysis based on CWEA 2020, CWEA 2021, Energy Iceberg 2020a

Figure 15.3: Number of direct investments of EU players in China and Chinese players in EU



Note: Includes the following type of deals: Corporate merger & acquisitions, private-equity buy-outs, strategic joint ventures and project acquisition.
Source: JRC analysis based on Pitchbook data

Figure 15.4: Destination of new VC/PE investments with a EU (left) and Chinese (right) investor in wind energy in the period 2008 - 2019 (total value of deals)



Source: JRC analysis based on Pitchbook data

15.3 China's investments in the EU target the entire wind energy supply

Apart from the above-mentioned partnerships, direct Chinese investments in the EU have focused on M&As, private equity buy-outs, strategic joint ventures and project acquisitions. By contrast, there were only eight investments from the EU in Chinese companies, most of them based in Taiwan or Hong Kong (Figure 15.3).

Chinese investments target the entire value chain including manufacturing plants, developers, stakes in energy utilities, entire wind farms or providers of AI based systems, in order to expand operations to markets outside China. Investment targets are located in most of the leading EU wind energy markets (Belgium, Denmark, Germany Spain and Ireland), and in smaller or emerging countries, in terms of wind deployment, such as Greece, Portugal and Sweden. Most of these investments are made by the smaller-to-mid sized central government-owned power utilities, particularly China General Nuclear Power, China Three Gorges, the China Resources Group or the State Development and Investment Company.

15.4 In the field of wind energy, bilateral venture capital and private equity investments between China and the EU are marginal

New VC/PE investments[113] in wind energy are limited in both the EU and China compared to other regions, in particular India and the US. In 2019, global VC/PE wind investments rose to about 18% (EUR 472 million) in the renewable energy sector, though this was significantly lower than at the beginning of the decade, indicating the greater maturity of the sector (Frankfurt School-UNEP Centre/BNEF, 2020).

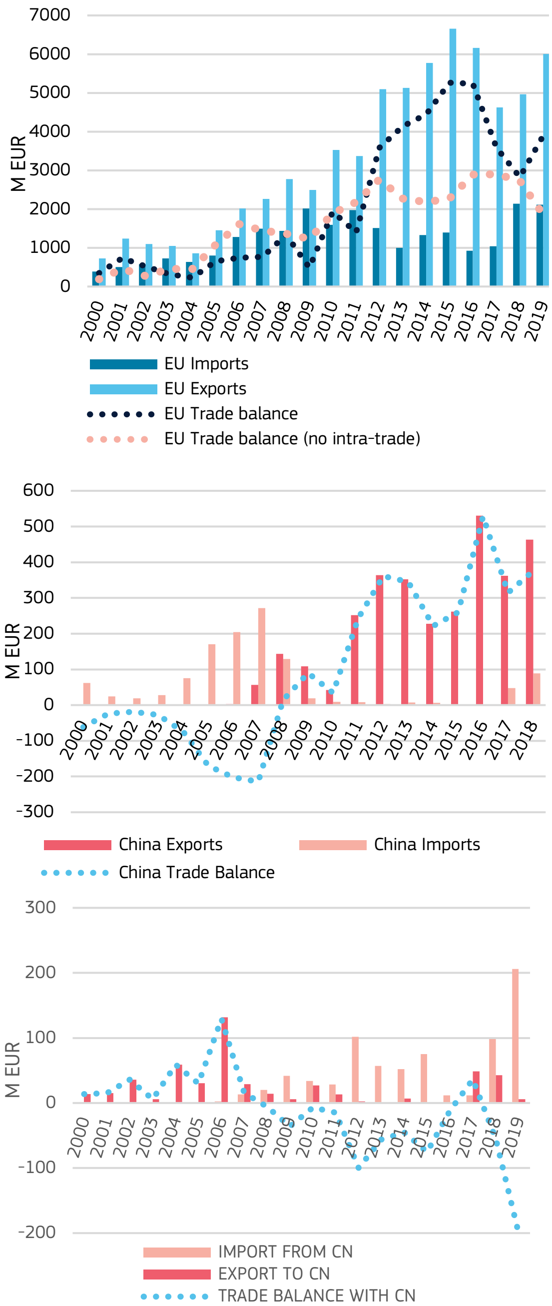
Since the early 2000s, the EU and China[114] have accounted for around 31% and 6% respectively of new wind VC/PE investments in the world. However, neither invested in the other region. Most EU VC investments remained within the 27 Member States (51%) followed by the US (41%), the UK (2%) and Norway (1%). Similarly, the destination of most Chinese VC deals (11 out of 15) was within China, however in terms of total capital invested, Chinese VC deals in the US (55%) surpass those made in China (45%) (Figure 15.4).

15.5 Trade flows in wind energy-related products indicate persisting barriers to the Chinese market

Over the last two decades, the EU has had a positive trade balance in electric generating sets (see Figure 15.5, top). In 2018, EU countries accounted for nearly 90% (EUR 6 billion) of global exports (EUR 2.9 billion when assuming a single market no intra-EU trade).

Following the introduction of a set of policies to protect China's domestic market, including the National Development and Reform Commission and State Council notices on local content requirements in 2005 and direct subsidies for eligible manufacturers in 2008 (Yuan et al. 2015), imports of wind generating sets to China have fallen sharply since 2007. By contrast, exports rose as wind equipment was shipped globally.

Figure 15.5: Import, export and trade balance in wind energy related goods (850231, Electric generating sets; wind-powered) of the EU (top), China (centre) and between EU and China (bottom)



Source: JRC analysis based on COMEXT and COMTRADE data

As such, since 2008, China has had an increasingly positive trade balance (see Figure 15.5, centre).

China's market barriers become apparent when assessing the trade balance with the EU. Since China's restrictive wind market policy began, a record trade deficit of EUR 200 million for the EU was recorded in 2019 (see Figure 15.5, bottom). In the same period, China's market size grew much more than the EU's. Around 21% of Chinese wind-related exports in 2018 went to the EU.

Although market barriers are not in place, the EU wind energy market is still led by local manufacturers. Looking at the EU as a single market, around 92% of the wind capacity deployed in 2018 originated from EU-headquartered manufacturers (Figure 15.6, Uihlein et al., 2019). Likewise, turbine sales outside China show the technological leadership of European original equipment manufacturers (OEMs) vis-á-vis Chinese counterparts. Outside China, European OEMs were responsible for between 73% and 82% of installed capacity (Lacal-Arántegui, 2019). Among countries exporting to the EU, only China increased its share of exports both to the EU and worldwide between 2010 and 2018 (Figure 15.7).

15.6 Protection of IP remains key in securing future technological leadership

China ranks first in wind energy patent filings, having overtaken the EU in 2009. However, China focuses on patent protection mainly in its home market, as only a small fraction of its inventions are protected by other patent offices outside China. Around 2% are high value inventions (see Figure 15.8)[115] (JRC, 2020).

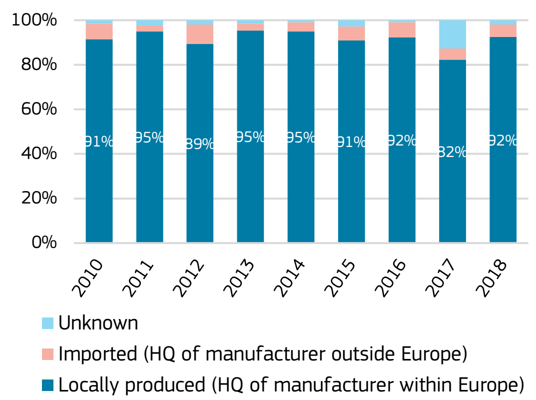
Chinese companies have diversified their patenting activity in recent years. Patenting increased in the area of grid-connected applications and, more recently, in the categories 'onshore towers', 'components or gearboxes' and 'turbine control systems' (see Figure 15.9). This trend is even more pronounced for the category 'turbine control systems' when assessing only high value inventions.

Both inventions and high value inventions show that Chinese knowledge stocks in wind energy were limited in the early 2000s and are still limited compared to the EU when looking at high value inventions. Yet, technology diffusion of European knowledge stocks through trade (OECD/DG Trade, 2021) did not occur (see Figure 15.5) as China protected its domestic market[116].

To acquire relevant knowledge and overcome the technological gap, Chinese OEMs build on technology cooperation with foreign firms (Watson et al., 2015) and licensing followed by strategic purchases of selected foreign wind firms (from blueprinting concepts to knowledge absorption). Targeted areas of wind technology that are most vital for catching up with European manufacturers in the offshore and grid integration sector included drive trains (permanent magnet direct drive technology); super compact drive technology and electronic control components of low-voltage ride-through technology (WPM, 2020b).

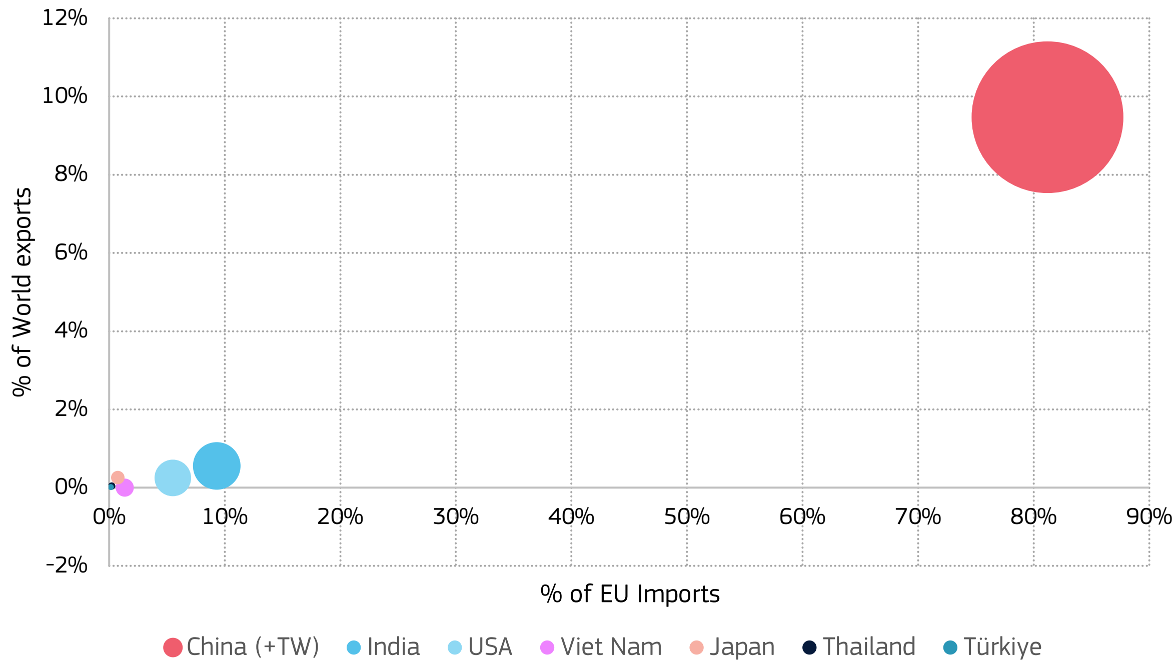
There is evidence that foreign companies struggle to protect value which does not rest on patented/registered IP but on trade secrets and know-how. (TPI Composites, 2020). In particular, knowledge transfer also takes place in the EU directly, as many Chinese OEMs have established their R&D centres in EU Member States (Envision Energy ApS in Denmark, XEMC Darwin in the Netherlands) to generate international patents through their European subsidiaries (Lam et al., 2017).

Figure 15.6: New installed wind capacity (onshore & offshore) in Europe - local vs imported assuming an European single market



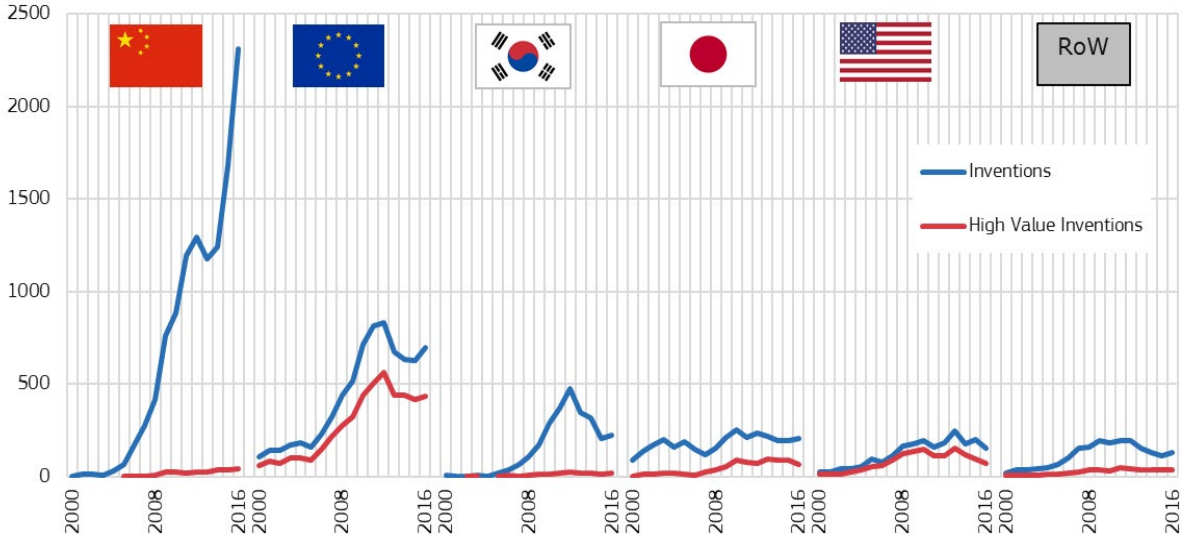
Note: Differentiation by country of origin of the manufacturer
Source: JRC Wind Energy Database

Figure 15.7: Leading countries importing wind energy related goods (850231, Electric generating sets; wind-powered) in the EU and their global export share in 2018



Note: Size of bubble corresponds to relative EU import share among the leading countries
Source: JRC analysis based on COMEXT and COMTRADE data

Figure 15.8: International comparison of the inventions filed and high value inventions in wind energy technologies



Source: JRC based on data from the European Patent Office (EPO)

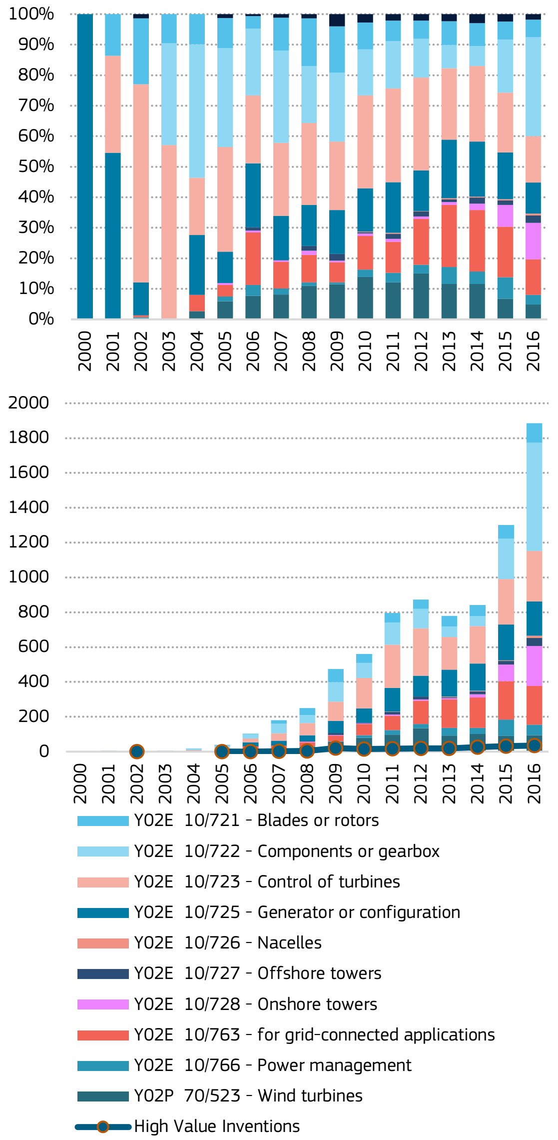
However, comparing high value inventions of the leading wind OEMs since 2010 shows that EU, US and Japanese companies are ahead in the major patent offices (EPO, USPTO, SINO). Only Envision Energy ApS can be found within the top 10 companies (see Figure 15.10). A similar picture can be obtained for high-value inventions filed in the Chinese patent office, with only Goldwind and Envision showing increased patenting activity (Hu et al., 2018)[117]. Looking ahead, there is an indication of China's increased interest in innovations in offshore wind (e.g. R&D in up-scaled wind turbine capacity and components for development of deep sea wind power; key technologies for testing and verification of large offshore wind turbines) and the roll-out and development of offshore wind (CIF, 2019; CWEA, 2019; JRC, 2020).

15.7 Growing demand for rare earth material increases the EU's dependence on China

China has a dominant role in the supply chain of materials and components for wind turbines. It accounts for over half of the production of relevant components and over one third of the production of raw and processed materials. China's role is particularly crucial in the manufacturing of permanent magnets for wind turbine generators. The country accounts for more than 60% of the global extraction of rare earth elements (Alves Dias et al., 2020) used in permanent magnet manufacturing and it has used its control of primary resources to expand its dominance in the downstream steps of the value chain.

In 2014, China already accounted for approximately 80% of global manufacturing of permanent magnets (Roskill, 2015; Eggert et al., 2016), while today it accounts for approximately 90% (Adamas Intelligence, 2019). The European Commission has forecast that demand for rare earth elements to be used in turbines deployed in the EU will rise significantly, on the back of the deployment of increased renewable capacity and in line with the ambitions of the European Green Deal. Unless the situation changes, this may lead to an increased dependence on Chinese suppliers.

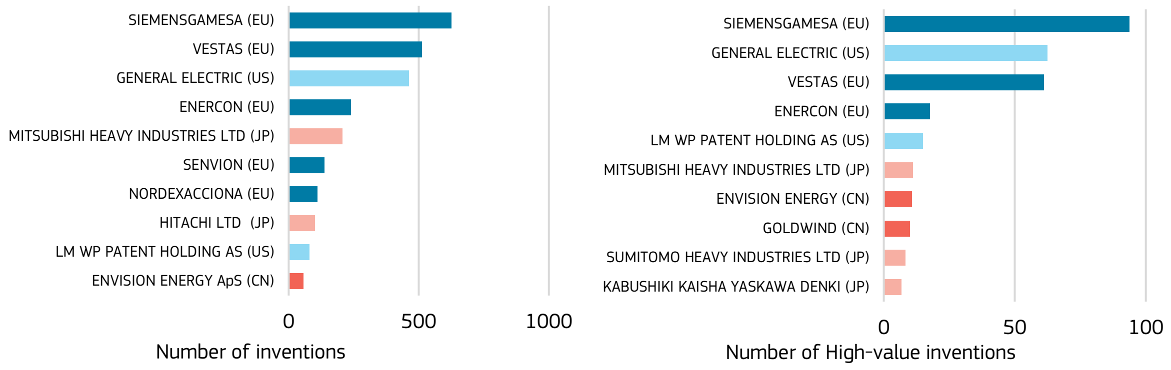
Figure 15.9: Chinese inventions filed by CPC category in wind energy technologies.



Note: Analysis of inventions with a CPC code indicating wind turbine subcategory

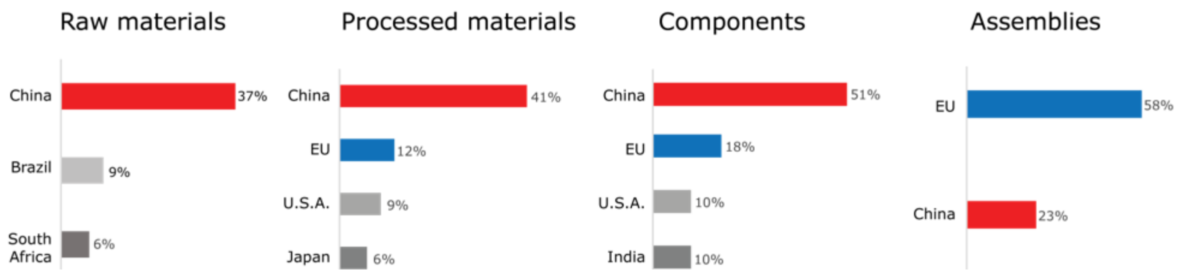
Source: JRC based on data from the European Patent Office (EPO)

Figure 15.10: Top 10 companies filing inventions (left) and high-value inventions (right) on wind energy in the period 2010-2016



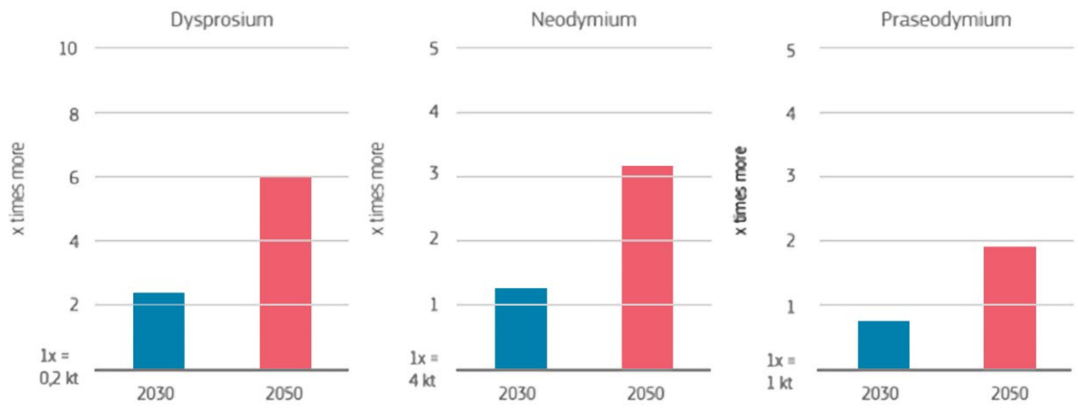
Note: Country of origin based on location of parent organisation
Source: JRC based on data from the European Patent Office (EPO)

Figure 15.11: Top players in the supply chains for wind turbines



Source: European Commission, 2020

Figure 15.12: Potential increase in demand of rare earth elements thanks to the future deployment of wind turbines in the EU



Source: European Commission, 2020

SUPPLY CHAINS FOR ENERGY TECHNOLOGIES

16.1 China dominates the supply chains for energy technologies

China is one of the major players in the supply chains for energy technologies, covering nearly all the steps from raw materials to final products. Figure 16.1 highlights the Chinese share in the supply chains for solar panels, wind turbines and li-on battery production. In each case China accounts for over 30% of the raw materials produced worldwide, and around 40-50% of processed materials, such as alloys and refined metals. China accounts for more than half the production of components and assemblies for the three technologies, except for manufacturing of wind turbines, for which the EU is in the lead. As already reported in the previous edition of this report (JRC, 2019), China has a particularly dominant role in the supply chain of solar panels, as it has been the largest manufacturer of solar cells and modules since 2007, now accounting for 70% of their production.

Thanks to its natural abundance of raw materials and its strong industrial push, China has secured its position as a key supplier of materials for energy technologies, and is using its prominent role to attract more advanced stages of production, with higher added-value.

One example is that of permanent magnets used in some wind turbines and electric traction motors. In 2018-2019 China was reported to control up to 70% of the mining, 85% of the processing and 90% of the refining processes for their key raw materials. Thanks to its proximity to the producers of raw materials and to the availability of cheap labour, China's manufacturing capacities for alloys and permanent magnets have expanded significantly, reaching 90% of global production of permanent magnets and specific alloys (Adamas Intelligence, 2019). China has also taken steps towards nationalising much of the value chain for these strategic industries, beginning with the consolidation of its rare earths mining and separation sector in six state-owned companies.

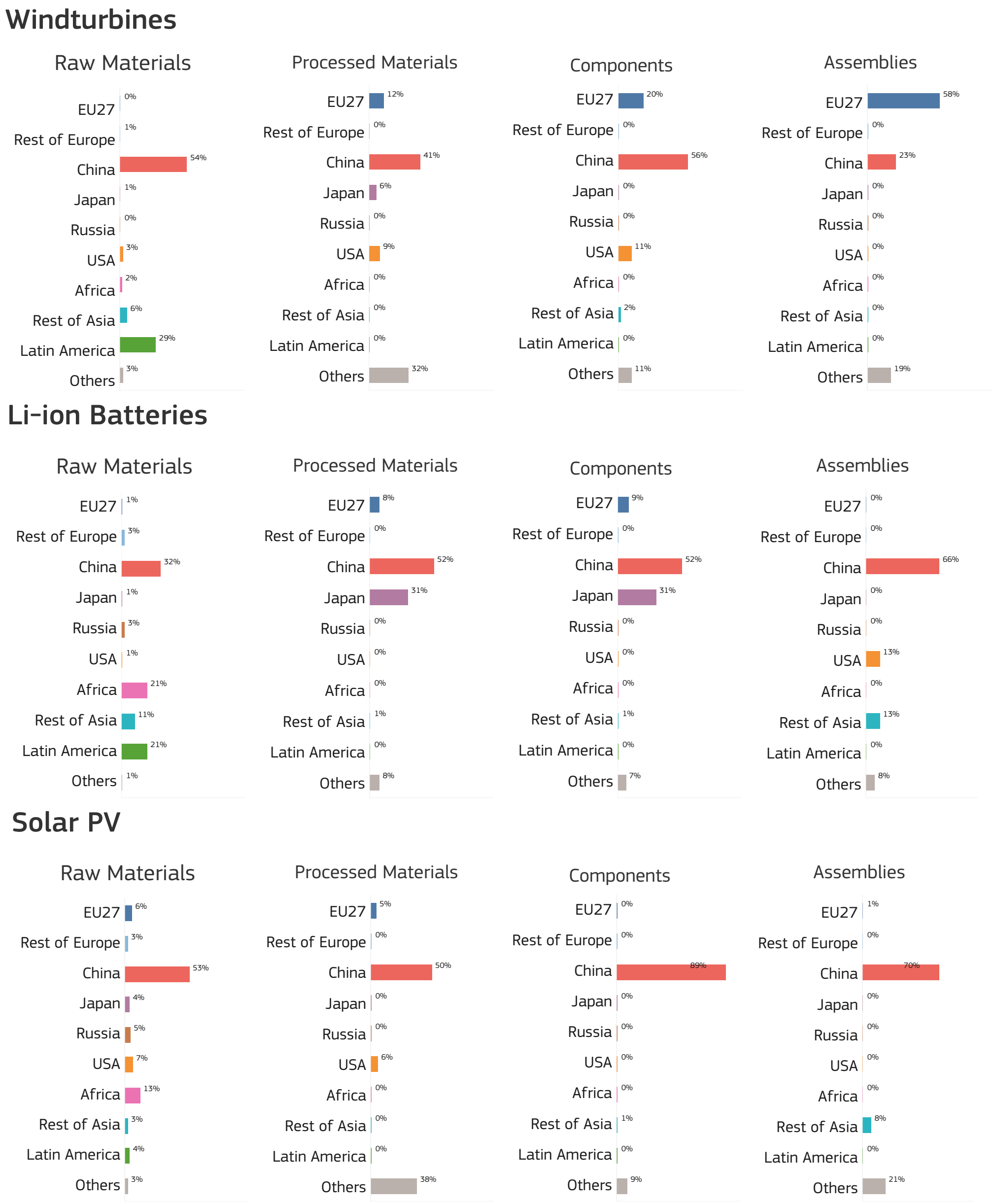
16.2 China's role in the supply of rare earth elements will be challenged, and undocumented production might remain a problem

Neodymium, praseodymium, terbium and dysprosium are rare earth elements used in the manufacturing of the most commonly used permanent magnets, which are a key technology for wind turbines and electric vehicle motors. In 2019, China accounted for 66% of their production, and for 62% of production of rare earth elements in general (Alves Dias et al., 2020). However, due to the investments that followed the 2011 rare earth price crisis and to an increased awareness of global supply dependencies, China's market shares are shrinking (Figure 16.2).

Many countries have supported investments in mining exploration and development projects, which will lead to a more diverse supply (Forbes, 2020; Reuters, 2020b). Changes have been already visible recently, with the Mount Weld mine begin operations in Australia and the Mountain Pass mine reopening in the US. As shown in Figure 16.3, Canadian and Australian mines are expected to begin operations soon and to acquire significant shares of production. If Chinese production remains equal to the current official production quotas (IMCOA, 2018), this could lead to a reduction of China's share of global production to only 25% by 2030.

This estimate is on the basis of Chinese official production, and assuming that its official production quota will remain unchanged. However, the situation may change if we take into account Chinese undocumented production. Several sources have reported information on mines that are operating without official licences, especially in the South of China (IMCOA, 2018; Packey & Kingsnorth, 2016).

Figure 16.1: Top players in the supply chains for solar panels, wind turbines and Li-ion batteries



Source: European Commission, 2020

Figure 16.4 shows our estimates of the ratio of documented and undocumented production for different rare earth elements. Although estimates of undocumented production vary greatly, its volume is likely close to that of official production for several elements, and particularly for heavy rare earths which are the least abundant and most expensive ones.

Other than representing an issue in terms of supply and market competitiveness, the presence of a large undocumented production is worrying from an environmental point of view. China is reportedly taking action to reduce undocumented production and minimise the environmental impact of licensed mines (Reuters, 2016; Reuters, 2019; Standaert, 2019). The effects of the new enforcements and regulations are already noticeable and could become more visible in the coming years.

16.3 China may evolve from a net exporter to an importer of rare earths

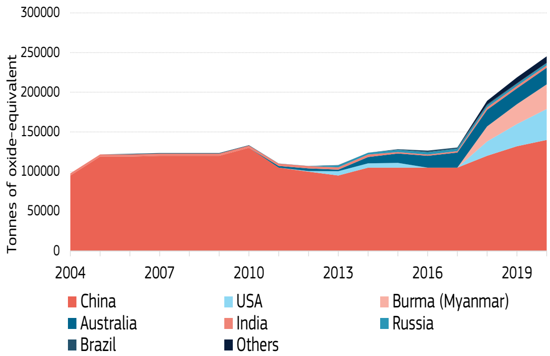
The demand for rare earths used in permanent magnets is bound to increase, mainly for uses in wind turbine generators, electric vehicles motors, consumer electronics and hard disk drives (European Commission, 2020). Figure

16.5 shows the amount of rare earths that will be needed to manufacture permanent magnets for wind turbines and electric vehicles worldwide.

As China is currently home to the vast majority of magnet manufacturing facilities, Chinese internal consumption is bound to increase as well. The country already accounts for 70-75% of global rare earths consumption (IMCOA, 2018), a share that is increasingly difficult to meet with internal production. In 2017, China's consumption rose above the yearly national production quota fixed by the Chinese government (Shen, Moomy, & Eggert, 2020) with the resulting market gap being filled by increased imports and undocumented mining. While this may create a positive effect in the global rare earth market, it could also lead to more supply bottlenecks. It may also lead to sustainability issues due to the increase in artisanal mines, which are poorly compliant with environmental standards.

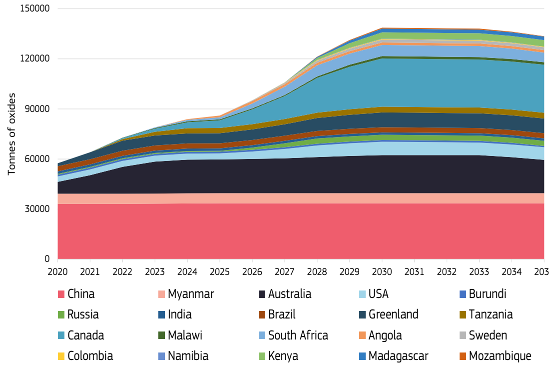
Rapid rates of mineral depletion in southern China, the region best known for undocumented mining, might also challenge overall production in the long run (Seaman, 2019) and China may find itself increasingly dependent on countries such as Myanmar for its rare earths supply.

Figure 16.2: Production of rare earth elements ores 2004-2019 (Chinese official production only)



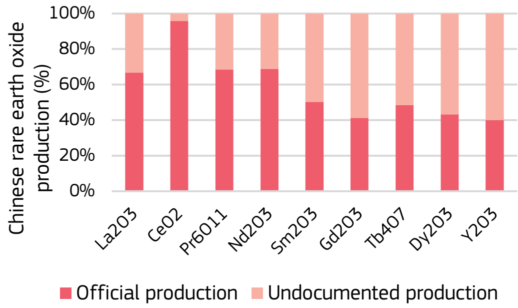
Source: USGS (2005-2020), mineral commodities summaries

Figure 16.3: Future distribution of rare earth supply (oxides used in permanent magnets only)



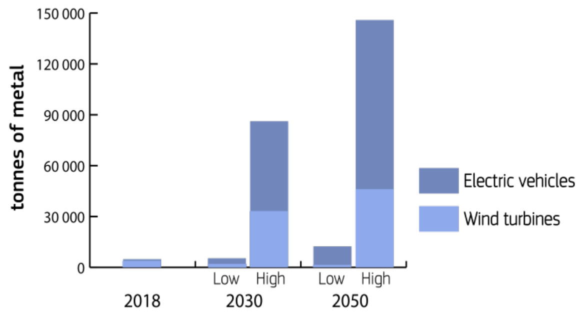
Source: JRC (Alves Dias et al., 2020)

Figure 16.4: Shares of official and undocumented production of various rare earth oxides in China in 2019



Source: JRC, based on (IMCOA, 2018)

Figure 16.5: Projected demand of rare earth elements for wind turbine in electric vehicles and wind turbines in low demand and high demand scenarios



Source: JRC (Alves Dias et al., 2020)

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LIST OF TABLES, FIGURES, AND BOXES

ENDNOTES

[1] Throughout the whole report we refer to the EU as EU27: from 1 February 2020, the 27 European Union countries after the UK left the EU.

[2] This chapter makes use of trade data from the International Trade and Production Database for Estimation (ITPD-E) created by Borchert, et al. (2020) and hosted by US International Trade Commission (https://www.usitc.gov/data/gravity/itpde.htm). It entails 243 countries for the period 2000-2016. For each pair combination of trading partners, it provides information on the total amount of international trade as well as the intra-national trade. Thanks to the inclusion of intranational trade flows, we can calculate the Trade integration index and the Market Accessibility index. This database also considers sector disaggregation that we use for the sectoral analysis.

[3] The market potential index considers the countries' factor endowments and consumer preferences for goods coming from a given origin. As a result, any change in trade frictions, factor endowments and consumer preferences would directly affect the market potential and, therefore, the market accessibility of a country.

[4] Head and Ries (AER, 2001)

[5] as Jacks and Novy (JIE, 2018)

[6] Trade penetration indicators are the result of EU competitiveness with respect to China. One indicator to assess EU competitiveness is through the Terms of Trade (ToT). ToT is the ratio between the prices of EU exports to China over the prices of EU imports from China. A high ToT indicates a loss of competitiveness of EU exports with respect to Chinese imports.

[7] This chapter evaluates the degree of overall import dependence in the EU at product level (over 4,000 categories) using Eurostat´s PRODCOM database, as well as the relative import dependence on China and its global market share based on UN´s COMTRADE data. EU import dependence using PRODCOM refers to the average of available years between 2015-2019, while the share of EU imports from China and the share of China in world exports using COMTRADE refer to 2017. World exports are computed using exports at product level for the 125 countries with the largest total value of exports. PRODCOM and UN´s COMTRADE categories matching uses the 2007 Harmonized System (HS) classification at 6-digit level.

[8] Import dependence is measured as the percentage that imports represent over the total supply, that is, imports plus own production across EU countries; hence, a higher degree of overall import dependence is in principle associated with a higher vulnerability to global supply disruptions in the corresponding product category.

[9] The measure used here corresponds to CDI2 as defined in the staff working document 352 (2021) "Strategic dependencies and capacities", page 21.

[10] Both charts in Figure 1 show the degree of EU import dependence as a percentage of total EU supply, and the share of China in total EU imports. They only differ in the reference used for drawing the size of the bubble, which on the upper side is the value of total EU imports in each product and on the lower side the value of EU imports from China. There are however important differences in terms of the import dependence metrics.

[11] Tables 3.1 and 3.2 show a selection of 25 product categories that are ranked by the value of total EU imports and by the degree of overall import dependence, respectively

[12] HS codes starting with 84-85, 87-88.

[13] HS codes beginning with 61, 62 and 64.

[14] HS codes 852351 and 844331, respectively.

[15] Both charts in Figure 1 comparing at product level the share that EU imports from China represent over the total EU imports; and the share of China in world exports. Charts only differ by how the size of the bubble is defined: total EU imports on the upper side and EU imports from China on the lower side.

[16] HS codes beginning with 84 and 85.

[17] HS codes : 852580 'cameras', 844331 'multifunction printers' and 852351 'flash memory cards'.

[18] HS code : 853400.

[19] On the new debate, see for example; "Coronavirus will change the way the world does business for good" (Financial Times, 8 April 2020) and "Coronavirus is disrupting global value chains. Here's how companies can respond" (World Economic Forum, 27 February 2020).

[20] https://voxeu.org/article/resilience-versus-robustness-global-value-chains

[21] WCO HS classification reference for COVID-19 medical supplies edition 3, updated on 2 June 2020. http://www.wcoomd.org/-/media/wco/public/global/pdf/topics/nomenclature/covid_19/hs-classification-reference_edition-3_en.pdf?la=en

[22] The different types of COVID-19 products by broad categories are: COVID-19 test kits/ instruments and apparatus used in diagnostic testing, protective garments and the like, disinfectants and sterilisation products, oxygen therapy equipment and pulse oximeters, other medical devices and equipment, other medical consumables and Vehicles. Note that for the latter, as there is no clear delimitation at 8-digit level of ambulances, we have left them aside since the trade flows could have included trucks, fire trucks and other motor vehicles, depending on the type of engine.

[23] Pressure Swing Adsorption (PSA); Oxygen therapy equipment (OZO); alcohol solutions (ALC); Pulse oximeters, monitoring devices and laryngoscopes (DEV); COVID-19 Diagnostic Test instruments and apparatus (INS); Women´s or unisex protective garments for surgical/medical use (WC); Light-emitting diode "LED" lamps (LED)

[24] https://www.nytimes.com/2020/03/13/business/masks-china-coronavirus.html

[25] The use of surveillance data allowed us not only to complement the vulnerability analysis but also its robustness. Our results suggest that EU supply chain in COVID-19 goods has proven to be quite robust in terms of ability to maintain operations during a crisis, as confirmed by the continuous trade flows between EU and China even in the full-lockdown periods.

[26] Here we break down Economic Fitness into 22 sectors (grouped in 7 categories), that have been identified as Priority industries for China (see Box 2). We also include an additional sector derived from the WCO COVID-19 Medical Supplies list.

[27] The sectors considered in this short analysis are collections of products classified according to the Harmonized System at 6 digits. The sectors' definitions have been provided by IFC-World Bank2 in the context of a JRC-IFC collaboration. The sectors were defined in order to match the priorities defined in the 13th Five Year Plan issued by the Government of China. These sectors also appear to have a significant but not perfect overlap with the MIC2025 priorities. Further information is provided in Cader, 2017 and Cader, 2019.

[28] China Statistical Yearbook of S&T 2001 and 2018

[29] This is based on a version of the right-hand side graph of Figure 3, with the same axis, but showing only the top 50% investors. This figure is available upon request.

[30] This appears to be indicative of the effect that the Chinese government's tax incentives provide to companies with a high share of R&D expenditure.

[31] In the analysis only PCT and EPO patents were considered.

[32] An annex on IP practices and the IP enforcement system in China is available upon request.

[33] The Revealed Technology Advantage (RTA) index provides an indication of the relative specialisation of a country in a certain technological field. It is based on patent applications filed under the Patent Cooperation Treaty. In the present report we use the definition provided by the OECD: "a country's share of patents in a particular technology field divided by the country's share in all patent fields. The index is equal to zero when the country holds no patent in a given sector; is equal to 1 when the country's share in the sector equals its share in all fields (no specialisation); and above 1 when a positive specialisation is observed" (OECD Science, Technology, and R&D Statistics, OECD iLibrary, https://www.oecd-ilibrary.org/science-and-technology/data/oecd-science-technology-and-industry-outlook/revealed-technology-advantage-in-selected-fields_data-00673-en).

[34] PATSAT includes altogether only 617 patents in the field of nano-technology for 2019, 667 for 2017 and 588 in 2015. It is not clear whether there are indeed so few patents in this field or it is a coverage problem of the patent database.

[35] The European Quantum Communication Infrastructure (EuroQCI) Initiative, https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci

[36] See for example the European Commission press releases of 13 June 2019 and 28 February 2020, https://ec.europa.eu/digital-single-market/en/news/future-quantum-eu-countries-plan-ultra-secure-communication-network, https://ec.europa.eu/digital-single-market/en/news/austria-bulgaria-denmark-and-romania-join-initiative-explore-quantum-communication-europe

[37] Structure of quantum computation query to the EPO GPI database: "CPC = G06N10/00 or IPC = G06N10/00 or (WORD = (quantum +1w computer#) or (quantum +1w computation#) or (quantum +1w computing) or (quantum +1w error? +1w correction) or (quantum +1w simulation#) or (quantum +1w memor*) or (q#bit#) or (quantum +1w algorithm?) or (quantum +1w software) or (quantum +1w information))". G06N10/00: "Quantum Computers, i.e. computers based on quantum-mechanical phenomena". This query structure is designed to catch all relevant, patents but does so at the price of retrieving some which are only loosely related to quantum computing; we estimate that false positives are between 10 and 20% of the total. Every application is attributed to the country where the applicant is headquartered: to give some examples, Huawei applications filed in Germany are attributed to China, Toshiba applications filed in GB are attributed to Japan, and Hewlett Packard applications filed in the UK are attributed to the USA, as well as Accenture applications filed in Ireland.

[38] Structure of quantum communications query to the EPO GPI database: "IPC = H04B10/70 or CPC = (H04L9/0852 or H04L9/0855 or H04L9/0858) or word = ((quantum +1w key* +1w distribution) or (quantum +1w cryptography) or (qkd) or (quantum +1w repeater*) or (quantum +1w communicat*))". H04B10/70: "Photonic quantum communication"; H04L9/0852: "Quantum cryptography (transmission systems employing electromagnetic waves other than radio waves, e.g. light, infra-red"; H04L9/0855: "involving additional nodes, e.g. quantum relays, repeaters, intermediate nodes or remote nodes"; H04L9/0858: "Details about key distillation or coding, e.g. reconciliation, error correction, privacy amplification, polarisation coding or phase coding". This query structure is designed to catch all relevant patents but does so at the price of retrieving some which are only loosely related to quantum communications; we estimate that false positives are between 10 and 20% of the total. Every application is attributed to the country where the applicant is headquartered. Sometimes however complex situations are encountered: for example, the Geneva-headquartered firm IdQuantique is owned with a controlling stake by South Korea Telecom, and operates a joint venture with the Chinese firm China Quantum Technologies (QTEC). In this case, we attributed to Switzerland patent applications by IdQuantique and to China patent applications by QTEC, thus actually short-changing South Korea.

[39] 4 fields out of the total of 22 included in INCITES

[40] Similarly to the RTA, the Revealed Scientific Advantage (RSA) is a specialisation index for a given country in various scientific fields. It can be defined as a country's share of publications in a particular scientific field divided by the country's share of publications in all scientific fields. A value that is greater than 1 shows specialisation.

[41] An annex on EdTech developments and performance in China is available upon request.

[42] This is the case of, for instance, the Shandong Communications Administration, the Hunan Police Academy, the Shanghai Public Security Bureau, the Chinese People's Liberation Army, the People's Hospital of Guangxi Zhuang Autonomous Region.

[43] The last revision of the Patent Examination Guidelines is expected to enter into force with the revised Patent Law on June 1 2021

[44] In fact, many countries are adapting patent examination rules in view of the nature of AI. A comparative study of patent eligibility of AI in China, Japan and the US shows that, while Japan has the most relaxed regulation, both China and Japan consider granting pure algorithm patents. The US had, at least until 2019, the most restrictive procedure for patent eligibility, but it is being relaxed in the newest revision (Hu, S., 2020).

[45] Several studies analyse the issue from different perspective and metrics and find overall lower performance for Chinese patents (Fisch et al., 2017; Christodoulou et al., 2018; Boeing at al., 2019).

[46] http://english.www.gov.cn/statecouncil/ministries/202102/06/content_WS601e351bc6d0f725769453b4.html

[47] Defined as co-patenting or collaborating in frontier research. The latter refers to publishing in the top international AI or Robotics conferences.

[48] Half of Chinese companies are large or very large.

[49] This business type corresponds to firms that develop AI patents for their own products or production processes in a main activity other than AI. These firms contribute to the AI technological development and uptake in all sectors of the economy.

[50] E.g. Lenovo, Angang Steel, Huawei Devices, Hisense Air Conditioning, SAIC Motor.

[51] E.g. China Petroleum, Sichuan Changhong Electric, Beijing Aerospace Measurement & Control Technology

[52] Based on the textual information contained in the activities of the collected microdata regarding agent's publications, patent applications and firms' main activity description, we infer their technological content and, through a topic model, identify the thematic areas or technological subdomains of AI.

[53] The Revealed Comparative Advantage (RCA) for country Ci and topic kz is defined as:

$$RCA_{C_i,k_z} = \frac{\frac{A_{C_i,k_z}}{\sum_z A_{C_i,k_z}}}{\frac{\sum_C A_{C_i,k_z}}{\sum_{C,Z} A_{C_i,k_z}}} = \frac{\frac{sum\ of\ activities\ of\ country\ C_i\ in\ a\ topic\ k_z}{sum\ of\ activities\ of\ country\ C_i\ in\ all\ topics}}{\frac{sum\ of\ worlwide\ activities\ in\ a\ topic\ k_z}{sum\ of\ worlwide\ activities\ in\ all\ topics}}$$

where $A_{C_i,k_z} = \sum_j A_j^{C_i,k_z}$ is the sum of activities of all players in country Ci and topic kz.

Activities considered include patent applications and publications. Also the description of the main activity of the firms is considered. The RCA indicator takes values ≥ 0, without an upper limit. In practical terms, most values lie below 5. The value RCA = 1 reflects the benchmark represented by the world average. Values > 1 reveal a comparative advantage.

[54] Data from The Conference Board (TCB) - Total Economy Database (TED), original database. According to their description, the alternative GDP estimate for China tries to remedy the issues in official statistics, like "structural breaks in employment statistics, implausibly high labour productivity for 'non-material' services and inconsistencies between output measures in industrial statistics and National Accounts."

[55] We cannot take into account possible price level differences between Chinese regions, which might magnify the difference between the more advanced and the less advanced regions. On the other hand, Chinese regions are very large (in comparison with NUTS2 regions in the EU, for example), thus disparities at a more detailed territorial level are probably even higher.

[56] Employment includes employees, self-employed, unpaid family workers and the military.

[57] Aggregate labour productivity growth is not simply a weighted average of sectoral productivity growth. In fact, it is a function of within sector productivity growth, the relative productivity level of sectors and employment shares of sectors.

[58] The incremental capital-output ratio (ICOR) measures how many units of investment are needed for increasing GDP by one unit. This indicator was calculated for all investments (gross fixed capital formation) and for R&D expenditure.

[59] For most countries, we can see a similar picture if we use labour productivity growth instead of TFP growth. In case of China, both the official and alternative labour productivity growth data are higher than of any economy with similar or higher level of R&D expenditure.

[60] World Bank only has data until 2018

[61] World Bank only has data until 2018

[62] As GDP/capital data at the end of the time series are quite similar for official and for alternative data, we put only the official data

[63] According to the World Bank's data catalogue, "Economic Fitness is both a measure of a country's diversification and ability to produce complex goods on a globally competitive basis. Countries with the highest levels of Economic Fitness have capabilities to produce a diverse portfolio of products, ability to upgrade into ever-increasing complex goods, tend to have more predictable long-term growth, and to attain good competitive position relative to other countries."

[64] The economic fitness of a country is calculated as the sum of the complexity of the goods it exports (Box 1). The complexity of a good is derived from the set of countries exporting it. Countries are then ranked, based on the economic fitness value.

[65] World Bank only has data until 2018

[66] As GDP/capital data at the end of the time series are quite similar for official and for alternative data, we put only the official data

[67] as GDP/capital data at the end of the time series are quite similar for official and for alternative data, I put only the official data

[68] In the text the term FDI deals is used when referring to acquisitions of equity stakes of at least 10% of the capital of the target company. The term foreign investor is used whenever this investor is ultimately controlled by a non-EU subject (either a company or an individual). For further details, see Gregori, Nardo, Ndacyayisenga and Rancan (2019).

[69] FDI greenfield projects, as opposed to the foreign M&A deals previously analysed, are investments aiming to set up a new installation built from the ground by a foreign investor

[70] Such as the new Dutch R&D centre from Syngenta, majority-owned by the China National Chemical Corporation, which was launched in May 2020.

[71] These three companies are to be banned by the US according to the 2019 National Defense Authorization Act and many countries due to US extra-territoriality trade issues. Results on Chinese FDI into EU for 2020 show a drastic reduction in Manufacturing: 6 projects in 2020 compared to 60 in 2019. However, it is difficult to disentangle the effect of the US ban on Chinese actors from the COVID-19 pandemic which brings most countries to lockdown.

[72] The logarithm of the number of Chinese deals in the EU in each NACE sector occurred in the period 2013-2020 is positively and significantly correlated with the logarithm of EU imports from China and Hong Kong in the same sector.

[73] We rely on the Eurostat classification of economic sectors according to their technological intensity.

[74] Data on trade flows in 2020 report an increase in EU imports of low-tech products from China, which have been deter-mined by the COVID-19 pandemic.

[75] From the beginning of the 2020 Covid-19 pandemic, greenfield shows a decrease of 66% (section 1.4) on a year on year comparison over the first 9 months of 2020. This means that patterns of investment have been deeply affected by containment measures: it is not clear yet when the type of investment will start again. Greenfield projects need efficient infrastructure enabling visits to potential sites and clarity on the potential incentives to settle. For these reasons we are not commenting 2020 data.

[76] Orbis CrossBorder Investment database is providing an estimate of the number of jobs created if it is disclosed in the project's description. The estimates of number of jobs created is corresponding to the average value observed on pro-jects having the same sectoral activity and the same origin and destination. It allows to obtain the number of jobs created, but also in a similar fashion, the capital expenditure for most of the greenfield projects: less than 5% of the projects have this information missing. Data reported here are transaction-based and are not referring to a specific year and we have no insurance at which stage – year- of the project, the jobs would be created or the capital would be spent. It also means that the data are not reporting the net value in the case of closure of some businesses due to the opening of a new infrastructure.

[77] See Statista Research Department, Nov 26, 2020

[78] See Eurostat estimations. The exchange rate used is 1EUR/1.1213USD. Notice that EU average hides large intra-EU differences, from 44.7 EUR of Denmark (50.12 USD) to the 6 EUR of Bulgaria (6.73 USD).

[79] Only acquisitions with an initial stake of less than 20% and a final stake of at least 50% were kept in the sample, to exclude all the capital increase deals that did not change the current status of ownership.

[80] While technological diversification is the expansion of a firm's technology base into a wide range of technology fields, technological coherence is typically defined as the degree to which technologies in a technology portfolio are related to one another (Leten et al., 2007).

[81] Details on the methodology are found in Pugliese et al. (2018).

[82] The sample in Bankscope is made of 33 billion EUR.

[83] Refer to the World Bank Financial Development Database.

[84] in previous analysis the IMF pointed to a larger amount of doubtful loans (IMF 2016b), with some analyses suggesting levels as high as 20% (Fitch 2016).

[85] https://www.bloomberg.com/news/articles/2020-06-17/china-wants-banks-to-cap-their-profit-growth-to-single-digits

[86] https://www.imf.org/en/News/Articles/2020/09/24/sp092420-securing-china-s-post-pandemic-recovery

[87] Overall, China's debt across all sectors (household, government, and corporates) lies around 300% of GDP (Figure 7).

[88] Business models analysis aims at understanding how banks operate in funding and lending, how much diversified are their activities distinguishing between pure commercial banks and banks highly involved in trading. Here we focus on few aspects which can used to characterize a bank's business model: customer deposits, corporate loans, and financial assets.

[89] The Financial Stability Board publishes the list of global systemically important banks (G-SIBs). The assessment is based on five criteria: size, interconnectedness, lack of readily available substitutes or financial institution infrastructure, global (cross-jurisdictional) activity and complexity.

[90] Tier 1 ratios represent the highest quality share of regulatory capital and made of equity and reserves. (see also Table 1 in Jiang, H. & Zhang, 2020 which ranks Chinese institutions first for the amount of Tier 1 capital held in their balance sheets). The rise in leverage ratio is mainly due to an increase in the amount of core capital, given that also total assets have been increasing as previously discussed.

[91] Industrial and Commercial Bank of China, China Construction Bank, Bank of China, the Agricultural Bank of China, Bank of Communications, China Development Bank Corporation, Postal Savings Bank of China Co Ltd

[92] Refer to the World Bank Financial Development Database.

[93] Financial Stability Board in its "Global Monitoring Report on Non-Bank Financial Intermediation 2019"; (https://www.fsb.org/wp-content/uploads/P190120.pdf).

[94] To quote the speech of Jack Ma at the Bund Summit of 24.10.2020: "there is not a financial system in China actually.

[95] https://hk.appledaily.com/opinion/20201108/TRMUNM72DRAQJNCG3ON2JUUF4A/

[96] February 2020 survey conducted by Tsinghua University and Peking University of 995 coronavirus-impacted small and medium enterprises showed that 85% did not have enough cash on hand to survive a three-month shutdown.

[97] Share of material resources used which came from recycled waste materials.

[98] OSCr is the share of secondary materials in interim outputs, which consist of all wastes and emissions after the use phase.

[99] Internet plus Circular Economy encompasses, for example, "Internet + used goods" and "Internet + resource recycling" to promote the integration of online and offline recycling and sharing/reusing activities.

[100] Comprehensive indicators: measure the overall productivity of main resources, such as fossil fuels, metals, minerals, and biological resources, the recycling rate of the main waste streams from agriculture, industries, urban construction, and urban food etc. Specialised indicators: measure specific streams of resource productivity, waste recycling rates, and the value added by recycling industries. Supplemental indicators: focus on the end-of-pipe treatment of waste, such as industrial, solid, and wastewater municipal waste, and the emission of main pollutants.

[101] The full set of sectors also includes automobile manufacturing industry, new material industry, food and beverage industry, chemical products manufacturing industry, new energy industry, textiles and clothing industry, electrical machinery industry, mechatronics industry, metal smelting industry, paper products industry, environment protection industry, agricultural and food processing industry, building materials industry, petrochemical industry.

[102] You can access the greening of the BRI platform on the Green BRI Initiative Center website.

[103] RFID stands for "radio frequency identification"

[104] ISO stands for "International Organisation for Standardisation"

[105] Open strategic autonomy is defined as the EU's commitment to open and fair trade, preserving the benefits of an open economy and supporting partners around the world to lead renewed and reinvigorated forms of multilateralism. At the same time, the EU is aware of the need to reduce its dependency and strengthen its security of supply across key technologies and value chains (COM/2020/456 final). This could include defining pathways for achieving the twin transitions and the pace with which they can be achieved, mapping critical emerging technologies, sectors and products, and options for new industrial alliances and diversification of trading partners (COM(2020) 493 final).

[106] Air pollution is mostly related to the combustion of various types of fuels. The particulate matter (PM), ozone (O3), nitrogen oxides (NOx), sulphur dioxide (SO2), carbon monoxide (CO), and volatile organic compounds (VOCs) cause a wide range of respiratory and cardiovascular diseases, premature morbidity and mortality. PM with a diameter of less than 10 microns (PM10), including fine particles less than 2.5 mi-

crons (PM2.5) pose the greatest risks to health as they are capable of penetrating peoples' lungs and entering their bloodstream (WHO, 2021).

[107] In 2012, the Chinese government published for the first time the Ambient Air Quality Standards (AAQC) for ambient particulate matter PM2.5 (MEP, 2012). The standards have two grades that apply to different fields. The Category I standards, which apply to areas such as national parks, set 24 h and annual average limits of 35 and 15 µg/m3, respectively. The Category II standards, applying to general areas, limit daily and annual averages to 75 and 35 µg/m3, respectively.

[108] Liu and Wang's (2020) results show that comparable percentage reductions in anthropogenic VOCs to that achieved for NOx could have prevented the increases in urban O3 concentrations. They thus recommend that VOCs controls be implemented in current and future emission-reduction measures to improve the overall air quality.

[109] JRC 2020, Analysis based on data from Chinese Wind Energy Association (CWEA) and BNEF

[110] See manufacturers of subcomponents in IEC certifications of Enercon and GE wind turbines: https://www.iecre.org/certificates/windenergy/pdf/IECRE.WE.TC.19.0043-R0.pdf, https://www.iecre.org/certificates/windenergy/pdf/IECRE.WE.TC.19.0027-R0.pdf, and https://mnre.gov.in/img/documents/uploads/file_s-1582795021354.pdf.

[111] For instance, the Chugoku Electric Power Company (Japan), J-Power (Japan), Korea Electric Power Corp. (KEPCO), KEPCO Shanxi International (Hong Kong) together own 52% of the shares of Gemeng International Energy, a Sino-foreign joint venture backed by the Ministry of Commerce and the Shanxi Provincial Government. Norway-backed NBT divested its shares in Chinese windfarms to China Datang. https://energyiceberg.com/china-wind-energy-developers/, accessed 29/09/2020.

[112] Currently about 10GW are under construction, whereas GWEC reports a vessel availability of 6GW/year.

[113] Includes early and late stage venture capital, private equity expansion capital but excludes private equity buy-outs.

[114] Including Taiwan and Hongkong

[115] High-value inventions (or high-value patent families) refer to patent families that include patent applications filed in more than one patent office.

[116] See National Development and Reform Commission (NRDC) and State Council notices in 2005 (70% of equipment in a wind power project must be domestically produced), in 2007 (import tariff and VAT exemption to domestic manufacturers for the import of key components and material of wind turbine) or in 2008 (direct subsidies for eligible manufacturers) (Yuan et al. 2015)

[117] e.g. Goldwind (Rank 14), Envision Energy (30), Sinovel (53), CSIC (119), XEMC Darwind (124), Guodian UP(194), XEMC(204), Vensys (424)

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