## B 5 THE CHALLENGE OF CHINA

### China as a growth engine for the world economy

The rise of China to being one of the world's leading economic powers, as well as China's enhanced efforts in science, research and high technology make it necessary to examine the Chinese innovation system in depth. Germany's competitive position is strongly influenced by China. For the past three decades, China has displayed impressive economic growth, and the country also takes a leading role in driving and consolidating global economic development. To date, annual average growth rates have amounted to approximately 10 percent. Even the global economic and financial crisis in 2008 and 2009 did not curb China's extraordinary economic development. Thus, even in the course of 2009, China's GDP increased by 9.2 percent – compared with –0.7 percent worldwide, and –5.1 percent in Germany.[320] In 2010, China's GDP increased by 10.3 percent, and again in 2011 an increase of 9.2 percent was achieved.[321] After China had assumed Germany's position in 2007 as the third-largest economy worldwide,[322] it then went on to surpass Japan in 2010, which up until then had been the world's second-largest economy. Presuming that China's economic dynamics will largely remain the same, it is expected that soon China will surpass the United States, thereby becoming the world's leading economy.[323]

At the core of China's growth over the last decades are comprehensive, continuous reforms of the entire economic system. Introduced by Deng Xiaoping in 1978, reforms were initially limited to attempts to deregulate the agricultural sector. Encouraged by the success of these measures, further deregulation processes were initiated, first in the industrial sector, and then also in the services sector, albeit to a limited extent.[324] Despite the introduction of these economic reforms, the one-party system under the Chinese Communist Party (CCP) remained largely untouched.

China's transition into a market economy system has been accompanied by measures to attract settlement of foreign companies in China. The government in Beijing opened up selected parts of its markets, while at the same time demanding that foreign investors transfer technologies and know-how to China. By enforcing joint ventures with Chinese state enterprises and by regulating the development of production and R&D in China, the country aimed to overcome its technological backwardness. Although Chinese companies managed to continuously improve their productivity and their capacity to innovative, Chinese industrial and technological policies still failed to produce the desired results for quite a long time. Chinese high technology products still depend to a large extent on know-how and primary products from abroad. Moreover, the quality of research and development has not yet reached the level of the Triad countries (US, Japan, EU).[325] In 2006, China's State Council therefore presented a long-term plan for science and technology, with the objective of boosting the performance of the Chinese innovation system, while primarily strengthening domestic skills.[326]

Special economic zones played an important role in the reform of China's economic system. These areas served the purpose of testing economic developments before they were applied on a national level. The launch of the first special economic zone in 1979, Shenzhen, marked the beginning of China's "open door policy", which has remained the official title since 1983. Step by step, the Chinese market was opened to foreign goods, technologies and investments. Soon foreign enterprises also began settling in China's special economic zones, which were characterised by a strong export orientation from the start and that often had a focus on particular industries. Yet, the relevance of these special economic zones has decreased since 2000, as the Chinese innovation strategy was readjusted and the entire system was opened up further. When China acceded to the World Trade Association (WTO) in 2001, the process of integration into the world economy was further enhanced. In the course of this, the role of the special economic zones was curtailed in favour of other structural changes.

### Economic growth accompanied by increasing inequalities

China's dynamic growth is accompanied by severe disparities and structural imbalances. Geographical, social and political disparities bear extensive potential for conflict, and tremendous efforts are made to bring them under control repeatedly. While the newly created growth centres significantly contribute to China's economic boom, they also exacerbate economic and social inequalities between the progressive coastal regions and the economically underdeveloped regions, particularly in the country's west.[327] The process of economic and social segregation is not just limited to the relationship between the provinces; it is also reflected in a substantial urban-rural gap and the rural exodus that accompanies it.[328]

Strong growth is accompanied by an increasing imbalance in the distribution of income and wealth. Today, China is characterised by severe social disparities and conflicts resulting from these disparities. Already in 2003, the wealthiest 10 percent of the population were allotted around 30 percent of total income, while the poorest 10 percent were allotted only 1.8 percent.[329] No less concerning is the fact that inequality within China's population is steadily growing. This increase in social disparities is illustrated by a rise in the Gini index[330] from 0.29 to 0.42 percent between 1990 and 2007.[331] On a positive note, the proportion of people living in poverty in China has decreased significantly. Measured against the World Bank's Headcount Index, which is commonly used for measuring poverty, China has made significant improvements since the 1980s.[332] At the same time, China ascended the United Nations' Human Development Index which measures the overall prosperity of countries.[333]

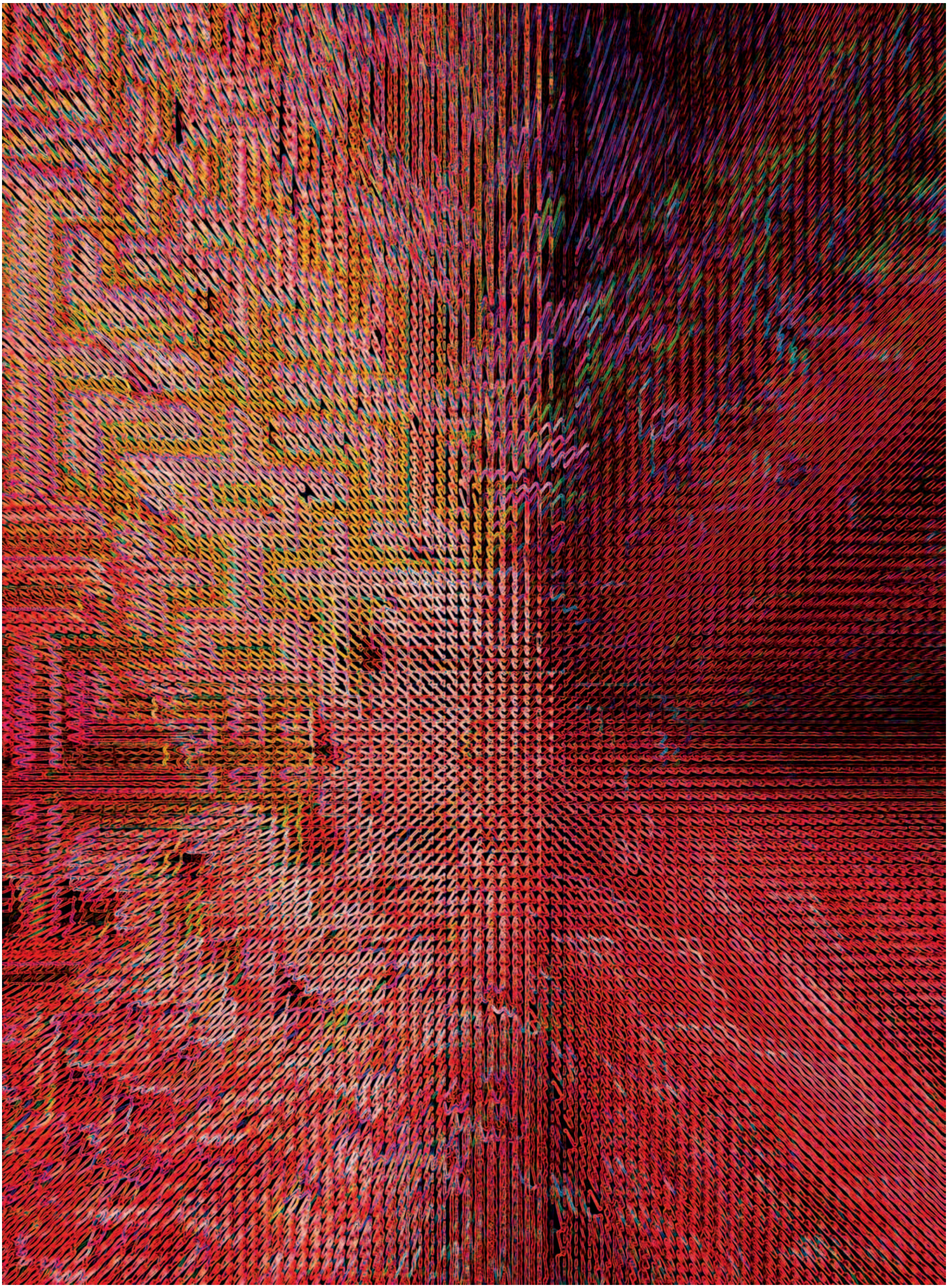
**Redesign of central policies**

Regardless of the comprehensive market economy reforms, the Chinese leadership continues to employ its Five-Year Plans as a major policy instrument. Although this is still the case, notions regarding the plans' function have changed over the years. Since the adoption of the 11th Five-Year Plan, these plans do not serve as "instructions" anymore but rather take on the role of "macro-steering" instruments.[334] While many of the planned targets have been achieved, and China's annual economic growth rate amounts to 10 percent – thus clearly exceeding the envisaged benchmark of 7.5 percent – China has only been partially successful in redesigning its growth model by giving it a stronger grounding in the domestic market. Not only the increase of innovative performance, but also the decrease in social inequalities and the development of domestic demand failed to live up to China's self-defined expectations. In fact, Prime Minister Wen Jiabao openly criticised China's economic development as being "imbalanced, uncoordinated and unsustainable."[335] China's transformation towards more social, technological and ecological sustainability shall now be enforced in the course of the 12th Five-Year Plan. Accordingly, the government's key objective of "growth" has now been replaced by that of "development". In this context, President Hu Jintao also stressed his notion of "inclusive growth", i.e. growth that is beneficial to all citizens.[336] Recent Chinese economic policy has been focussing on developing the domestic market and reducing China's dependency on export markets. To achieve this, China's leadership is willing to accept a decline in economic growth of approximately 7 percent per year.

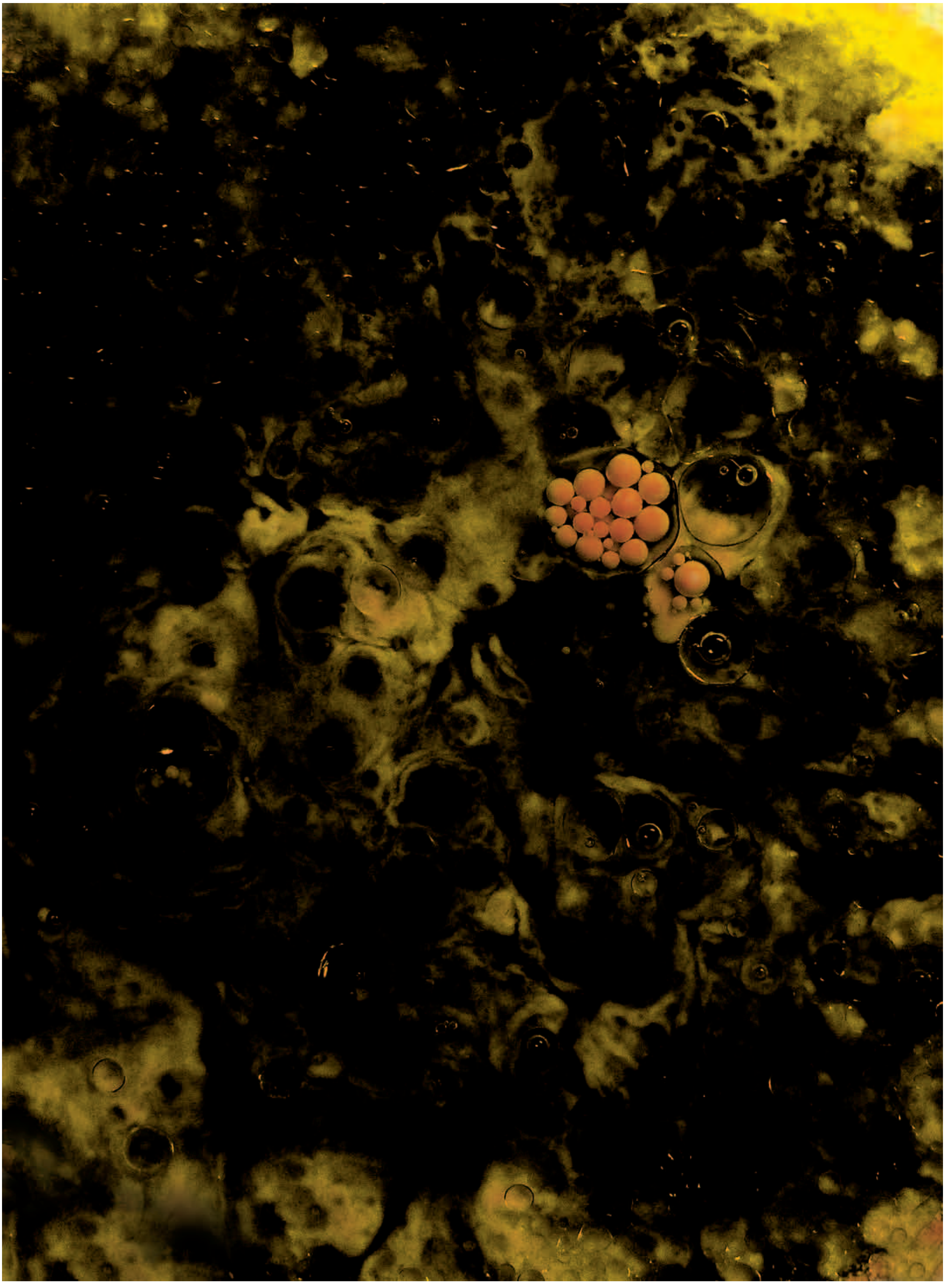
**Strong focus on research and innovation**

China has adopted an offensive innovation strategy that specifically focusses on developing science and research. Between 1995 and 2009, national R&D expenditures increased from USD 11 billion to USD 154 billion.[337] This corresponds to an average annual growth rate of 21 percent. In the same period, the OECD's average R&D expenditures increased by 6 percent per year, and Germany's R&D expenditures by 5 percent per year. China's steady increase in R&D intensity illustrates the country's strong focus on research and development. In 1992, the proportion of R&D expenditures of GDP was a mere 0.6 percent. This ratio was increased to 1.7 percent up until 2009. Today, China's research intensity is similar to that of Great Britain or the Netherlands. While the self-defined target of 2.0 percent of GDP for 2010 was not achieved, it is very likely that this target was met in 2011. The relative importance of R&D shall be further enhanced via additional public R&D efforts as well as promotional measures in the private sector. For 2015, the Chinese government aims at increasing R&D intensity to 2.2 percent of GDP, and for 2020 a benchmark of 2.5 percent is envisaged.[338]

Owing to an ambitious development of the national R&D system since 2000, China has managed to gradually advance its R&D capacities, at least quantitatively, to the level of several leading industrialised



7/10 Chinese symbols on dried fibre felt



8/10 Oil mixture with encapsulated liquid countries. At the start of the last decade, China thus surpassed Great Britain and France, and since 2006 China has spent, in absolute terms, more on R&D than Germany has. With R&D expenditures of USD 154 billion, China also replaced Japan in 2009 as the world's second most research-intensive economy, and Asia's most research-intensive economy.[339] The development of China's national R&D system is primarily owing to a strong increase in private R&D. Both Chinese companies and foreign corporations in China have been consistently increasing their R&D efforts. While R&D expenditures of the private sector amounted to only 0.25 percent of GDP in 1995, this value had been increased to 1.25 percent in 2009, with R&D expenditures of USD 113 billion. Also in this regard China exceeded Japan and is now ranked second place in the world, with approximately twice the amount of private R&D expenditure than Germany. With 26 percent, the annual growth rate of China's private R&D expenditure is substantially higher than that of Germany (5.4 percent), the United States (6.4 percent) and the group of OECD countries (6.5 percent). Yet, when comparing China's R&D performance on a global scale, it should be noted that vast differences exist between China's and the OECD countries' approach to data collection in the field of R&D.[340]

**China's industrial policy**

China has completed its transformation process towards a modern industrialised economy in the country's highly developed regions. In the course of this process, China consistently focussed on the most recent technology and foreign know-how. In the first phase of liberalisation between 1978 and 1995, the emphasis was placed on developing the manufacturing industry with an initial focus on wage-intensive and export-oriented industries. At the same time, China's development strategy also tackled the following four types of economic entities: (1) large, state-owned enterprises (SOE) that take on a key role in strategically important economic sectors such as power generation and telecommunications; (2) joint ventures between foreign enterprises and state-owned enterprises, e.g. in the automotive sector and the chemical industry; (3) newly emerging Chinese medium-sized enterprises with high growth potential; (4) subsidiaries of foreign companies with their own manufacturing plants and their own R&D.

Already in the mid-1990s, a strong focus was placed on high technology and knowledge-intensive industries and services sectors. Domestic R&D, the development of high technology sectors and the promotion of "national champions" were gaining ever more relevance. Alongside these efforts, the computer, electronics and telecommunications sector was further developed. In collaboration with companies from Asia and the United States, China set up offshore centres in China for use by foreign companies to produce for export markets. China thereby managed to expand value added and exports in the information and telecommunications industries. During the 10th and 11th Five-Year Plan, further key industries were integrated, with the aim of expanding production and development capacities in the respective sectors. Especially with regard to the development of the automotive and component supplier industry, the chemical industry as well as machinery and plant engineering, German enterprises played an important role both as ground-breakers and investors.

The measures described above have turned China into the "workshop of the world". In 1990, China still held the 7th position in the world's leading production locations for manufacturing industries. Back then, China's share in global value added in the respective sector amounted to no more than 3 percent. By 2007, China had managed to surpass leading competitors such as Japan and Germany and is now, with a share of 14 percent in global production volume, in second place after the United States. China is also becoming more and more important as a production location for cutting-edge technology goods.[341] With a proportion of 14 percent of gross value added in the field of cutting-edge technology, China came in second after the United States in 2007. This is also reflected in the country's export shares illustrated in Figure 22. China steadily increased its global export shares between 1995 and 2010 in the area of R&D-intensive goods.[342] In the same period, world market shares of both the United States and Japan decreased considerably. China's photovoltaics industry may serve as an example for the strategic development of the high technology industries (see Box 19).

BOX 19

## China's photovoltaics industry

Between 2000 and 2010, the global market for solar cell modules grew on average by more than 40 percent per year. In 2010 the total market volume reached a value of EUR 35 billion. The driving force for this rapid market growth was several countries' efforts to transform their energy supply systems into more sustainable models. In Germany, the implementation of this policy was largely based on the Renewable Energy Sources Act, in which feed-in tariffs are specified. These feed-in tariffs had a dimension that allowed for considerable profits not only for the producing solar energy sector, but also for investors in solar energy. Due to this, the sector saw a dynamic development in demand.

The Chinese government and Chinese companies were quick in detecting the growth potential of the solar market; from 2000 onwards, they started investing heavily in the development of photovoltaics production capacities. The Chinese government supported this process by making available extensive amounts of cheap capital.[343] In parallel with this, German and Japanese companies in particular swiftly expanded their production capacities, a process that led to a considerable overcapacity in the production of photovoltaic modules. Towards the end of 2011, a demand of approximately 20 GWp[344] was met by a module production capacity of at least 40 GWp. More than half of this production capacity is located in China.

Technological and market developments have led to a pronounced asymmetry: due to market launch programmes, the market for photovoltaic modules has been growing sharply and steadily, especially in Germany and several other European countries. Yet, a large proportion of products are sourced from China.[345] It should therefore be asked what impact this development is going to have on Germany.

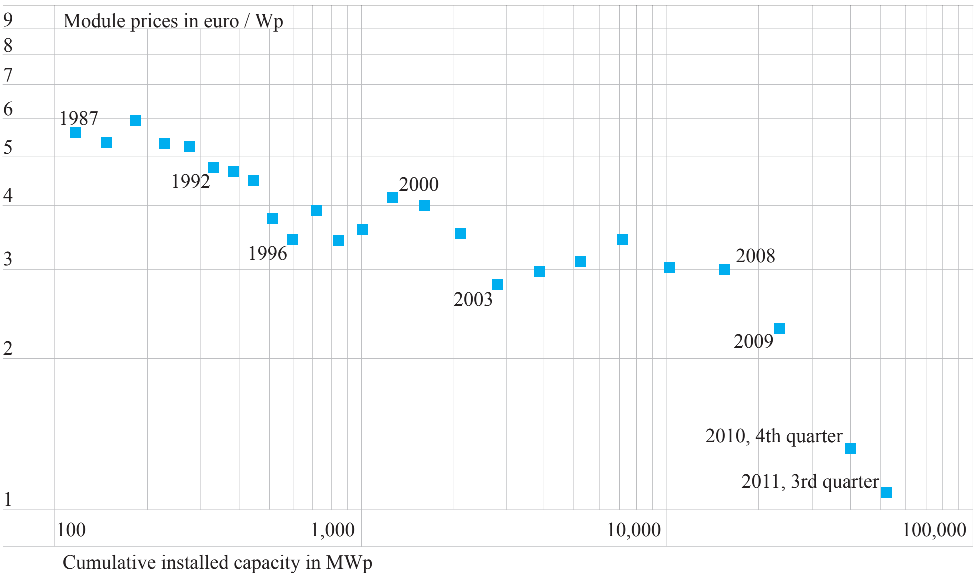
Technological progress, mass production, overcapacities in production, and the current economic climate have lead to a sharp price decline for photovoltaic modules (cf. Figure 21). This erosion of prices has not only considerably reduced the costs of solar energy; it has also led to dwindling profits for companies and investors worldwide. The price reduction in the field of photovoltaic modules is supporting Germany in developing a cost-efficient energy generation system that is environmentally acceptable[346] In late 2011, the proportion of solar energy contributions to the German energy supply was 3.2 percent; this rate is due to increase further due to continuing price reductions.

In the area of development and supply of production plants, Germany has benefitted from the worldwide growth of the photovoltaics industry. A large proportion of major, technologically relevant components from China's current production lines were supplied by German mechanical engineering companies.[347] At the same time, the export of turnkey production facilities and plant building served as the prime source of gain in know-how for Chinese companies in the photovoltaics industry. There is little doubt that several German companies are encountering economic difficulties caused by competition from China. Yet, it should also be noted that this is also true for large Chinese companies that will not be able to compete with cheap competition in their local market.[348]

In the area of photovoltaics, Germany provides an excellent industrial basis and arguably the world's best scientific infrastructure. Germany thus has the chance of serving the market segment for high-value, technologically advanced photovoltaics products. This is particularly the case as labour costs in photovoltaics – a semiconductor technology – are well below ten percent. Based on continuous innovation, a high-wage country such as Germany can thus continue to position itself clearly on the world market, both in application and production.

**Price trend for photovoltaic modules**

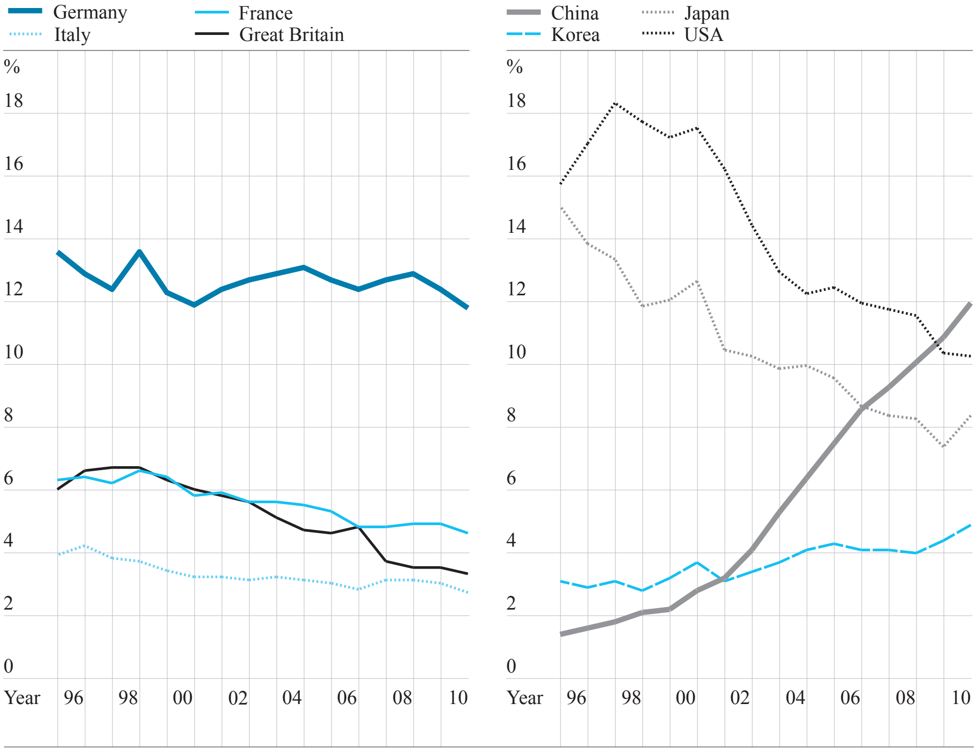
FIG 21




Source: Fraunhofer ISE and PSE Ag, annual periods 1987 – 2009; Solar Energy Research Institute of Singapore, Barclays Capital and Deutsche Bank, quarterly figures 2010 and 2011.
Price-experience curve for photovoltaic modules.[349] Both axes use a logarithmic scale.

**Structural change and development of export shares in the field of R&D-intensive goods[350]**
(shares in percent)

FIG 22




World trade share: share of a country's exports in world exports in percent. World exports for 2010 are based on estimates.
Source: Gehrke and Krawcyk (2012: 23).

**R&D investments by foreign enterprises**

In terms of China's technological development and modernisation, foreign enterprises have been paving the way and continue to do so. Foreign enterprises receive massive support from the Chinese central government and provinces, especially when they are willing to transfer R&D and advanced technology to China. Foreign companies, in turn, perceive China as an attractive and rapidly growing market that requires both long-term investment strategies and the necessity to comply with strict obligations. For many investors, business with China is both difficult and tempting. To enter the Chinese market, products and services have to be adjusted to customer needs and local standards. At the same time, companies that are active in China obtain important stimulus for innovation and new business models in Asia. China's transformation provides foreign companies with an important "real world experiment" with distinct learning effects: there is hardly any other country in which it is possible to study the world's most serious problems – such as climate change, urbanisation and the emergence of mega cities, as well as modern transportation systems – while actively participating in solving these problems. Onsite R&D facilitates the development of promising new solutions that will open up growth opportunities not only for other Asian markets, but also on a global scale.[351] China is shaping the important markets of the future, particularly those of emerging countries.

Foreign enterprises have thus attached high priority to entering the Chinese market and are, increasingly, building R&D facilities onsite. Today, these account for a substantial part of the Chinese economy's R&D expenditure. In particular, foreign enterprises account for leading high-tech developments and a high proportion of patent applications in China. In 2009, the Chinese economy's R&D expenditure amounted to USD 113 billion. Of this amount, approximately USD 19 billion was generated by foreign multinationals. This is complemented by investments from Taiwan and Hong Kong, amounting to USD 10 billion.[352] Between 2000 and 2009, the share of foreign companies in the total R&D expenditures of China's economy rose from 12 percent to 17 percent.[353]

The relevance of foreign R&D units is expected to increase further in the future. Since 2005, surveys among managers of multinational corporations show that China as a business location ranks at the top of their priority lists when it comes to developing R&D facilities.[354] This trend is further enhanced by the fact that the Chinese government expressly demands foreign companies to establish R&D centres in China once they have completed the development of domestic production plants. A large number of incentives and support measures at national level and in the provinces further add to this trend; especially since these are often coupled with the demand to generate and file patents nationally (see also the following sections on patent strategies).

R&D activities of multinational corporations are primarily focussed on sectors for which the Chinese market is particularly attractive. Moreover, in some technical areas, China can offer large numbers of well-trained R&D personnel, and some of the leading international research centres offer their services as partners.[355] In addition to this, the strong financial position of state-owned enterprises in particular provides further incentives for cross-border co-operation and the establishment of R&D in China.[356] The vast majority of R&D subsidiaries of foreign companies is to be found in the computer and information technology industry, software and IT services, telecommunications, semiconductor and consumer electronics, as well as the chemical and pharmaceutical industries.[357] With a large number of R&D facilities in China, US companies are the most active stakeholders in these sectors.

US investors are immediately followed by investors from Japan and Western Europe. German companies are playing an increasingly important role and have their own R&D facilities in China primarily in the electrical, chemical and pharmaceutical industries as well as in the automotive industry.[358] With its internationally-oriented centres of growth, China has turned into a major R&D location.[359] To date, the majority of foreign companies have been limiting their activities to adapting developments to Chinese customers' needs and local standards. Given the high mobility of Chinese personnel and the continuing gap in the protection of intellectual property, strategically important technologies and core competencies will continue to be concentrated in the foreign companies' home country or, respectively, developed at locations that are able to safeguard the company's internal protection of know-how.

BOX 20

**Electromobility in China**

In dealing with its immense challenges in the area of transport, China has put a strategic focus on electromobility. Growing traffic-related environmental issues caused by fossil-fueled cars are posing major environmental problems for China's mega cities. Electromobility does not generate any local pollutants[360] and is a low-noise mode of transportation. This makes electromobility a sustainable means of transport that is particularly suitable for use in mega cities.

China has the potential to become a lead market[361] in electromobility. This is primarily owing to the following points: (1) traffic problems in China's mega cities cannot be overcome on the basis of conventional drive concepts that are based on fossil fuels; (2) automobilisation in China's cities is largely oriented towards small cars, which makes the launch of or transition to electric vehicles easier than it is in Europe; (3) China has a considerable market for vehicles that are used solely in urban transport; (4) electric vehicles help China to reduce its dependency on fossil fuels.

China is already highly successful in employing electro scooters in large cities like Shanghai and Beijing: today, in their inner cities, fossil-powered scooters or motorcycles are only rarely used, and the benefits of emission-free transport are clearly demonstrated to the public. It should be kept in mind however that the technology used for electro scooters is very different from the technology used for electric cars. Yet, for essential components such as wheel hub motors it should be possible to benefit from the knowledge gained in the fast-growing market for electro scooters and apply it to the development of electric cars.

China has set itself ambitious goals in the area of electromobility: by 2015, one million electric vehicles are supposed to be in use, and ten million by 2020. The market launch of electric vehicles will be accelerated primarily via government subsidies for manufacturers and buyers.[362] Furthermore, electric vehicles are guaranteed permission for road travel, which is a prerequisite for operating a vehicle in China.

The German automotive industry is very active in China in the area of electric vehicles. In partnership with Chinese automotive companies, German manufacturers develop electric vehicles for the Chinese market. Thus Daimler is collaborating with BYD, Volkswagen with FAW, and BMW with Brilliance.[363] This type of partnership is a mandatory requirement by the Chinese government: other than partnerships, foreign companies have no other option to be active in the field of electromobility in China. In addition to these enforced co-operations, China is also strategically developing purely national industries in the area of electric vehicles and key components such as batteries.[364] The Chinese government supports these efforts to a considerable extent.

German universities and non-university research institutes are either very active in China, or progressing considerably in developing activities in China. Examples include: (1), the Fraunhofer-Gesellschaft's Center for Advanced Electromobility in Shanghai, which will be operated in close co-operation with Tongji University; (2) a BMBF-funded co-operation between nine German technical universities (TU9)[365] and five Chinese universities for the development of a German-Chinese research network; (3) the co-operation between the BMU (via its Development Co-operation Agency, GIZ) and the China Automotive Technology and Research Center CATARC in the area of electric vehicles.[366] In the view of the Expert Commission, these activities are not sufficiently co-ordinated, and the assumed benefit for Germany of these various R&D activities in China is not communicated adequately.

In the opinion of the Expert Commission, China, and not Germany, is building up a lead market in the field of electromobility. Germany still has the chance to establish itself as a supplier of vehicle components, information and communication technology, and high-value electric vehicles. To achieve this, it is crucial to develop a co-ordinated strategy between German industry, government bodies and research facilities.

It should be noted however that foreign enterprises, including German enterprises, keep expanding their R&D units in China and perform technologically advanced work in various fields that cannot be implemented elsewhere. This applies especially to fields that are characterised by a concentration of talent and promising markets in China. Examples include mobile communications, medical technology, new transportation systems, as well as Internet and e-commerce. Especially in the field of electromobility, China has initiated promising developments that attract the attention of foreign companies and research institutes (see Box 20). It is these fields that can accelerate leading developments in China and Germany. Hence, scientific collaboration between the two countries should be concentrated on these areas.

**Priorities of the 12th Five-Year Plan**

China's innovation policy and China's medium-term and long-term planning are largely determined by the State Council's "Steering Committee of Science, Technology and Education (SCSTE)". This steering committee consists of members of the major ministries and academies. SCSTE has prepared the National Medium- and Long-Term Plan for the Development of Science and Technology (2006–2020). The 12th Five-Year Plan serves to specify the scientific and technological priorities and identify the key areas of innovation policy for the period 2011 to 2015. The following innovation policy objectives outline the strategic focus of the 12th Five-Year Plan.

1. Promoting scientific and technological progress.
2. Accelerating the development of the economy's innovation system.
3. Expanding the scientific and technical infrastructure.
4. Policies and frameworks for the promotion of research and technological innovation.

China's industrial policy is largely determined by its priority on "New Emerging Strategic Industries" which has been specified by a high-level inter-ministerial working group led by the National Development and Reform Commission (NDRC). In the period 2011 – 2015, the following industries are in the focus of development planning: (1) the energy and environmental sector; (2) information technology; (3) biotechnology; (4) the capital goods industry (especially aircraft construction and mechanical engineering); (5) new energy systems; (6) new materials; and (7) automotive industry, electric vehicles in particular.

These seven industries and their respective sectoral and technological priorities are further specified in Box 21. Noteworthy in particular is the tenacity with which the objectives of growth and sustainability are pursued to an equal degree. Another striking feature is the scope and intensity with which China is tapping into these growth markets. The priority fields are largely the same as those that are on the development agenda of many of the highly industrialised countries such as the United States, Japan and Germany. In international comparison, the high degree of duplication becomes apparent. The Expert Commission therefore sees the necessity to carefully monitor the similarities between China's innovation policies and the Federal Government's High-Tech Strategy.

According to the 12th Five-Year Plan, China's innovation competence shall be substantially enhanced, with the aim of transforming the country from a technology follower to a technology leader. It is China's declared intention to build up their own highly developed research system and to cover and dominate the entire value chain in key areas of high technology. Furthermore, major emphasis shall be placed on domestic innovation, i.e. R&D that is decidedly Chinese in character and conducted in China, as well as intellectual property that is generated within the country. With its objective of "Indigenous Innovation" ("zizhu chuangxin") – more aptly translated as "self-owned innovation" – the Chinese government aims to strengthen innovation in national property that is controlled or dominated by Chinese right holders. The aim is to reduce the dependency on technology imports; an aim that had already been declared in the outline for the medium- and long term planning. Here, the catchphrase "Voluntary is the new mandatory" serves to describe the strong state influence on local and foreign innovators to subject any economic activities to the political mandate of national policies and to actively support the goals of the Chinese government.

In addition to this, high priority is also being attached to promoting the expansion and consolidation of large companies in key industries. The Chinese

BOX 21

**Innovation and development of new strategic industries**

1. **Energy conservation and environmental protection industries**
   Implement major exemplary projects in energy conservation and environmental protection, and promote the industrialisation of efficient energy conservation, advanced environmental protection and resource recycling.

2. **New-generation IT industry**
   Construct new-generation mobile communication networks, the new-generation Internet, and digital broadcast and television networks. Implement exemplary application projects of the Internet of things and special industrialisation projects of network products. Construction industrial bases of IC, panel display, software and information services.

3. **Biological industry/Biotechnology**
   Build databases of gene resources for pharmaceuticals, important plants and animals, and industrial microbial bacteria. Construct R&D and industrialisation bases for biopharmaceuticals and biomedical engineering products, biological breeding, testing, detection and fine breeding bases, and exemplary bio-manufacturing application platforms.

4. **High-end equipment manufacturing industry**
   Construct industrialisation platforms for home-made trunk and feeder airplanes, general-purpose airplanes and helicopters, and a spatial infrastructure framework composed of navigation, remote sensing and communication satellites, and develop intelligent control systems, high-class numerically controlled machines, high-speed trains and urban rail traffic equipment, etc.

5. **New energy industry**
   Construct industrial bases for new-generation nuclear power equipment, large wind power generating sets and parts, new assemblies of efficient solar power generation and heat utilisation, biomass energy conversion and utilisation technologies, and intelligent power grid equipment, and implement exemplary large-scale application projects of marine wind power, solar power and biomass energy.

6. **New material industry**
   Promote the R&D and industrialisation of carbon fibers, semiconductor materials, high temperature alloy materials, superconductive materials, high-performance rare earth materials and nanometer materials for aviation and spaceflight, energy and resources, traffic and transport, and major equipment.

7. **New-energy automobile industry**
   Conduct R&D and large-scale commercialisation demonstration projects for plug-in hybrid electric vehicles and pure electric vehicles, and promote industrialised application.

government aims to systematically promote its “national champions”, that is, strong global leaders with brand names of international reputation. In key industries, core elements of the value chain shall be provided by strong national companies. The stated goal is to “field” two competing Chinese world leaders in all of the major growth segments. Examples include Huawei and ZTE (telecommunications) and Lenovo (personal computers), all of which have gained an international standing, as well as other companies that are listed in Table 9.

### China’s public research system

The Chinese leadership has embarked on an ambitious innovation strategy, with the stated goal of turning the country into one of the world’s leading centres of innovation before 2020. Existing deficiencies in certain areas are planned to be overcome by applying “leapfrogging strategies” in key fields of science and technology.[367] To systematically expand China’s national innovation system, ten different types of measures shall be employed.[368] The government is taking steps to ensure that the defined target for 2015 is achieved, i.e. national R&D expenditure of

TAB 09 **Examples of Chinese world market leaders in growth areas**

| Growth area | Company | revenue in billion euro | R&D expenditures in billion euro | Employees |
|---|---|---|---|---|
| Mobile communication (manufacturers) | Huawei | 23.2 | 2.07 | 110,000 |
| | ZTE | 8.8 | 0.89 | 85,232 |
| Mobile communication (operating companies) | China Mobile | 60.7 | 6.07 | 164,336 |
| | China Unicom | 21.4 | n.p. | 215,820 |
| Consumer electronics | TCL | 6.5 | 0.23 | 50,000 |
| | Haier | 4.5 | 0.01 | 18,200 |
| Photovoltaics | Suntech | 2.4 | 0.03 | 20,200 |
| | Trina | 1.5 | 0.02 | 13,000 |
| Internet | Baidu | 1.0 | 0.09 | 11,000 |
| | Alibaba | 0.7 | 0.07 | 13,674 |
| Computers/ PC | Lenovo | 13.8 | 0.18 | 22,205 |
| | Founder TG | 0.8 | n.p. | 4,500 |
| Electromobility (battery technology) | BYD | 2.1 | 0.07 | 55,000 |

Source: Internet research based on annual reports for 2010. All figures refer to 2010.
(BYD: figures refer to 2007).

2.2 percent of GDP. This includes measures to stimulate R&D in the private sector, as well as active strategies for further expanding the public research system. The central government's declared goal is to significantly increase the research and technology budget's proportion of public expenditure. The provincial governments are also obliged to considerably increase their investments in R&D.[369]

In recent years, China's public R&D expenditures have been increased significantly, even though they could not keep pace with the dynamic expansion of R&D in the private sector. Between 1995 and 2009, overall R&D expenditures in the public research system increased by 15 percent each year (compared with this, R&D in the private sector increased by 26 percent per annum).[370] About 70 percent of publicly performed research is attributable to public research institutions and 30 percent to university-based research facilities. Compared with other OECD countries, China is characterised by a greater institutional separation between dedicated research institutions and higher education institutions. In China, high-level research with comparatively ample funding primarilytakes place at the institutes of the Academy of Sciences (CAS) and a few selected elite universities.[371] Several other universities that are part of Project 211 conduct research in a small number of selected fields.[372] Other than that, a very large number of China's universities are confined to their academic training role.

Due to the aforementioned increase in research spending within the public science system, China's research performance (as measured by publications) has also seen a rapid growth. This was further enhanced by efforts to realign and systematically evaluate research conducted. The number of publications in international journals has increased significantly. In 2010, Chinese scholars ranked second worldwide; in 2000 they had merely occupied the eight position. Yet, it should be noted that the quality and relevance of Chinese publications are still below global standards.

Between 2000 and 2008, the citation rate of Chinese publications rose from 1.3 to 3.1. However, the worldwide average is 3.7, and leading science nations achieve values above 5.0 (cf. Table 10 for an analysis of the structural changes in publications and citations).

In spite of these remarkable developments in terms of resources used (research input) and research results (such as publications), critical voices in China keep expressing concern over existing deficits. Above all, the following issues have been subject to criticism: the underfunding of the public research system, the brain drain of talented young professionals to the private sector and abroad, the overall insufficient quality of research, and the continuous problem of attracting and retaining top talents.[374] In China, basic research accounts for a comparatively small

TAB 10 **Shares of leading countries in publications from the Science Citation Index (SCI) and the Social Science Citation Index (SSCI)[373] as well as citation rates**
(shares in percent)

| | 2000 | 2008 | 2010 |
|---|---|---|---|
| **Share in publications** | | | |
| USA | 32.1 | 28.7 | 28.0 |
| China | 3.5 | 9.2 | 11.0 |
| Great Britain | 9.3 | 7.9 | 7.8 |
| Germany | 8.1 | 7.2 | 7.3 |
| Japan | 8.7 | 6.6 | 6.0 |
| France | 5.9 | 5.3 | 5.2 |
| Canada | 4.2 | 4.5 | 4.5 |
| Italy | 3.9 | 4.3 | 4.3 |
| India | 2.0 | 3.3 | 3.4 |
| Korea | 1.6 | 2.9 | 3.3 |
| | | | |
| **Citation rate** | | | |
| Worldwide citation rate | 2.9 | 3.7 | |
| USA | 4.6 | 5.6 | |
| China | 1.3 | 3.1 | |
| Great Britain | 3.8 | 5.4 | |
| Germany | 3.5 | 5.1 | |
| Japan | 2.7 | 3.6 | |

Source: Analyses from Web of Science, publications and citations in the SCI and the SSCI, based on Schmoch et al. (2012).

proportion of research. Staffing budgets and remuneration structures in the public research system are extremely unfavourable and unable to compete with those of the private sector.[375]

### Strategies for patent protection and law enforcement

At a very early stage, China recognised the strategic value of patents for the process of national development. Based on this insight, the Chinese patent law was reformed in several steps. Yet, the adoption of Western legal structures and legal systems will have to be reconciled with Chinese cultural paradigms and legal interpretations that still persist. Thus, in Chinese culture, imitation has been considered desirable for centuries. There is ample evidence for patent violations and product and brand piracy.[376] Thus it is for a good reason that political stakeholders from Western countries are attaching great attention to the subject of intellectual property in China.[377]

Also from within the Chinese system, a number of measures and policies have been implemented to promote patents and intellectual property and reconcile them with the national innovation strategy.[378] These measures, and the systematic expansion of R&D activities, have led to a sharp rise in the number of Chinese patent applications in recent years. Between 2002 and 2009, the Chinese Patent Office recorded an increase in patent applications from Chinese residents from 40,000 to 230,000 (representing an annual growth rate of 28 percent). The number of patents filed by Chinese researchers at the European Patent Office and the US Patent Office has also risen sharply. Individual Chinese companies such as Huawei and ZTE now occupy leading positions in rankings of international patent applicants.

The rapid growth in the number of patent applications should not blind us to the deficits that still exist. With a growth rate that is significantly higher than that of foreign companies, patent applications from Chinese applicants at the Chinese Patent Office have been increasing since 2004. Yet, the patent grant rate, i.e. the proportion of applications that result in an actual patent, is still very low in China (cf. Table 11).[379] In terms of patents granted, foreign applicants had been dominating up until 2007. Since 2008, Chinese researchers have been able to draw level with foreign companies in terms of patents granted. Yet, the time and expenses invested in the application are much higher, and a large number of patent applications still accounts for low-quality developments. The influence of multinational corporations on China's technological development remains to be high.

Another factor that complicates collaboration between Chinese and foreign corporations is the fact that technology developed in China-based subsidiaries are subject to priority registration with the Chinese Patent Office (SIPO). In the event that a foreign company is unwilling to follow this requirement, the company has to obtain prior permission from the Chinese government for conducting a priority application abroad. Multinational corporations have internal guidelines for international patent application, and these are often conflicting with the requirement of priority patent application in China. What is more, the initial assessment and granting of a patent application in China is often accompanied by language-related issues, and may also result in

TAB 11 **Development in patent applications and granting of patents by the Chinese Patent Office**

| | 2002 | 2004 | 2006 | 2008 | 2010 |
|---|---|---|---|---|---|
| **Chinese applicants** | | | | | |
| Patent applications | 39,806 | 65,786 | 122,318 | 194,579 | 293,086 |
| Patents granted | 5,868 | 18,241 | 25,077 | 46,590 | 79,767 |
| Grant rate (%) | 14.7 | 27.7 | 20.5 | 23.9 | 27.2 |
| | | | | | |
| **Foreign applicants** | | | | | |
| Patent applications | 40,426 | 64,347 | 88,172 | 95,259 | 95,259 |
| Patents granted | 15,605 | 31,119 | 32,709 | 47,116 | 47,116 |
| Grant rate (%) | 38.6 | 48.4 | 37.1 | 49.5 | 49.5 |

Source: SIPO Annual Report 2010.

considerable loopholes in global patent protection. Beyond patent application, additional restrictions on the export of products and technologies have been put in place for developments that China-based subsidiaries participated in. For a number of companies in the United States and Western Europe, this has led to major disruptions in transnational development ventures. Currently it is expected that foreign companies will be calling into question further R&D collaborations with China, or limiting their efforts altogether.

Due to the weakness of the Chinese patent jurisdiction, Western companies are unable to defend themselves effectively. The topic of "patent protection and intellectual property management in China" remains to be a central issue that affects collaboration with foreign partners. In the period of the 12th Five-Year Plan, and also in the long term, the expansion of China's innovation system should be accompanied by a further development of the patent system and patent jurisdiction. Any further advancement in this field should consider the interest of both Chinese innovators and partners from abroad.

This entails in particular the provision of active support for contract and licencing agreements in research and development. Foreign innovators in China should be equipped with sufficient rights to protect themselves against state interference with the foreign innovator's freedom of contract. In addition, threats via mechanisms such as compulsory licences and rights for the use of foreign technology should be avoided as much as possible.

### Standard-setting strategies in China

Today, one of the most important levers in the international innovation competition is an early influence on standards that are not only valid for local markets and certain groups of countries, but that also determine product configuration, entry conditions and the game rules employed in global markets. Influence on and control of standards is critical to a country's ability to develop its own innovative

BOX 22

### Patenting strategies in China

Chinese companies apply for large numbers of patents that are only copies or mildly modified versions of foreign technology. It is a common strategy of many companies to sift through foreign patent databases and specifically occupy any identifiable gaps in application. The corresponding areas of know-how that are otherwise unprotected are then registered in China and presented as original achievements.

Another common strategy is to register utility models that are attributable to existing patents, thereby obtaining protection for supposedly original inventions. This may even go as far as attempts to "overturn" the original patent applicant on the Chinese market. Because of this accumulation of patent and utility model applications attributable to an invention, – also known as "patent thickets" and "patent tsunamis" – foreign companies can be forced to enter into negotiations and cross-licencing agreements.

strength and avoid dependencies on foreign suppliers. With its initial focus on importing Western technologies, China was running the risk of becoming too dependent on standards that are controlled by leading foreign countries and organisations.

Based on its experience in the adaptation of technologies and advanced systems in the field of telecommunications, transportation technology and energy technology, China came to realise the threats of increasing dependency on imports and licence fees. To avoid further dependency, China decided to establish standards for the domestic market, which would have to be adopted by foreign companies. This was temporarily attempted in mobile phone standards and Internet standards, albeit with the result of sub-optimal solutions and dependencies on local suppliers. Furthermore, all-Chinese standards have the disadvantage of largely undermining subsequent export strategies for Chinese companies.

For a country like China, a workable alternative is the "standard leapfrogging strategy", whereby supplier groups on the world market are being observed with regard to their standards offered. The supposedly best standard is then selected, developed and tested. As a next step, a Chinese standard is developed, which is applicable to the large domestic market. Chinese companies, research organisations and national standard setting bodies are involved in the development and implementation of this standard. Yet, to ensure optimal solutions, leading foreign companies are also integrated into this process.

In strategically important market segments, it can be observed that this "standard leapfrogging strategy" is systematically applied. Foreign companies actively participate in the first phase. In parallel, Chinese suppliers are qualified as the central stakeholders. Standards and technical standards are then developed. Finally, the Chinese companies involved conquer the national market to the largest possible extent. At a later stage, Chinese suppliers also set out to enter international markets. Striking examples for this strategy can be found in the fields of telecommunications, rapid transit systems and wind energy. The "standard leapfrogging strategy" is made possible by a national standard setting policy that divides participants into two types of standard-setting consortia: full members and associate members; while the latter may even be classified as observers. Only Chinese companies and Chinese research organisations are entitled to obtain full membership. Full members are equipped with full voting rights and can actively participate in important steering committees, which largely determine the development of standards. Opposed to this, associate members have no voting rights, and they also pay a higher membership fee than full members. To date, foreign companies have only been allowed to participate in China's standard-setting consortia as associate partners.

Such discrimination against foreign companies with R&D and production facilities in China is extremely problematic and heavily burdens collaboration in important areas of innovation. Especially when it comes to future co-operation between Germany and China, the practices described above will have to be overcome. This applies e.g. to the fields of electromobility, environmental technology and renewable energy. In its 2011 position paper, the European Chamber of Commerce has presented recommendations for improving co-operation between Chinese and foreign companies through standard-setting agreements.[380]

**Conclusion and recommendations**

As one of the leading science nations worldwide, China is currently making a considerable effort to improve its position in several key strategic areas through its 12th Five-Year Plan. For Germany, these efforts entail opportunities, but also threats. Thus new perspectives for enhanced collaboration are opening up in areas that are beneficial for both countries. Yet, Germany also has to accept the increased risks and challenges that accompany it. In addressing these risks and challenges, German companies and research organisations can build on stable, longstanding relationships with their co-operation partners.

**International division of labour in progress: recognising the challenges**

China's position in global competition is becoming stronger and stronger. Especially through state influence on economic sectors and research areas, China is conquering more and more areas of expertise that have traditionally been occupied by Germany. In light of this, the further development of China's innovation system should be monitored with great attention and continuously analysed for opportunities and threats.

"China innovation" must be given high priority by Germany's policy makers; it should not be left to experts in companies, ministries and research organisations alone. In order to respond adequately to the challenge of China, the Federal Chancellery, the heads of the respective ministries, as well as academic bodies and the Federal Government's advisory committees should, on a regular basis, announce coordinated strategies for dealing with this issue. At intervals of about two years (i.e. twice per legislative term) the Federal Chancellery should specifically promote dialogue on "China innovation" and integrate key players into this process. A possible platform for this dialogue could be the Federal Government's Innovation Dialogue, which could address Germany's national China strategy as a special topic in due course. In addition to this, the "Research Union Economy – Science" *(Forschungsunion Wirtschaft und Wissenschaft)* and the scientific academies should also dedicate themselves to a greater extent to the subject of "China innovation".

**Strengthening co-operation with China on all levels**

On a federal level, several departments are involved in co-operations with China. The BMBF has initiated major projects in the field of scientific and educational co-operation. The BMWi is the lead agency in Chinese-German projects in the field of foreign trade policy, energy policy and standardisation work. Several other federal ministries (e.g. Ministry of Foreign Affairs, Ministry of Transport, and the Ministry of Environment) regularly deal with aspects of China-related collaboration. All these initiatives should be consolidated to a greater degree. Thus the Expert Commission recommends improving co-ordination between the participating federal ministries, but also between the *Länder* governments involved. This could be achieved e.g. by setting up an interministerial working group (consisting of BMBF, BMWi, BMU, BMA, etc.), which would offer guidance to strategic projects and also review the progress of collaboration between the two countries.

The Federal Government has initiated a process of enhanced collaboration as part of the 2011 German-Chinese intergovernmental consultations. Between the BMBF and the Chinese Ministry of Science and Technology (MOST), several co-operation agreements in the areas of research, innovation and education, as well as promising platform projects, have been launched. In parallel, several other federal ministries have launched important initiatives which are to be implemented via regular consultations at ministerial, secretary of state and head of department levels. The Expert Commission welcomes these initiatives and projects. To ensure the success of these newly established platforms and collaborative projects, and to draw a maximum benefit for both sides, it will be necessary to continuously monitor and evaluate the progress of projects, and to document both successful and unsuccessful examples of German-Chinese collaboration.

As regards the BMBF, the German-Chinese platform for innovation, research and innovation policy can be regarded as one of the major collaboration projects. In September 2011, leading experts from both countries laid the foundations for this project at a conference in Beijing. The launch of the platform will result in a subsequent conference to be held in Germany in 2012, and shall then be hosted on an annual basis. Important issues for the future dialogue between the two countries are: 1) innovation and standard setting in both countries; 2) patents and intellectual property, including IP management and licencing; 3) development of specific German-Chinese projects in the areas of electromobility, solar energy and hydrotechnology; 4) opportunities for bi-national R&D support programmes; 5) exchange of highly skilled personnel between both countries; and 6) establishment of a joint graduate programme with a focus on innovation research and innovation policy.

**Creating reliable framework conditions for intellectual property and standards**

The development of China's innovation system and the quality of China's co-operation with foreign partners heavily depends on the development of the patent system and a functioning system of intellectual property protection. The Federal Government should continuously monitor progress in intellectual property protection in China and regularly report on their findings. Collaboration between the EU delegation and the Chinese government in the field of patent protection and intellectual property should be continued and the previously developed recommendations should be systematically implemented.

The Expert Commission considers the development of norms and standards as an important starting point for promoting innovation projects in both countries and on equal terms. International, uniform norms and standards are preferable to unilateral national standardisation regulations. Chinese government agencies, companies and researchers should be confident and empowered to play an active role in key international standard setting organisations. But also the Chinese domestic market should place its focus on norms and standards that are fully compatible with international standards. In the event that national standards or modifications of international standards are continuously enforced in China, foreign companies should be enabled to participate as equal partners in Chinese standard-setting bodies and consortia.

The Expert Commission recommends strengthening co-ordination of German foreign science policy in China. Several major scientific organisations have each developed their own China strategy and established subsidiaries and research institutes in China. The large number of initiatives suggests that maybe too much of a good thing has been done. In the future, these diverse activities of foreign scientific organisations (DFG, FhG, HGF, MPG and others) should be consolidated even further, with the aim of strengthening the larger German scientific community in China.[381] Moreover, attention should be attached to avoiding too generous a transfer of academic results, especially in application-oriented areas. The exchange of scientific results and research groups should be balanced and mutually beneficial.

### Strengthening expert knowledge on China in Germany

Enhanced collaboration between China and Germany will require a large number of professionals who are familiar with both cultures and both economic systems. Other countries have introduced training courses and development programmes for managers, which combine technical-scientific training with language training and intercultural competence on China. Germany is still lagging behind in this regard. Especially when training future management personnel in the field of engineering, natural sciences, law and economics, more attention should be paid to building up expert knowledge on Asia – and China in particular – at an early stage. To achieve this, new training programmes and further education courses at universities, as well as collaborations between German and Chinese higher education institutions, should be systematically promoted.

### Maintaining technological advantages in photovoltaics and electromobility

Particularly in the field of photovoltaics, the development of a powerful Chinese industry has been fostered by providing virtually unlimited capital at extremely low interest rates. This has led to a substantial distortion of global competition in this field of technology. German companies have suffered greatly from this. The Federal Government should strive to swiftly eliminate this market distortion through agreements with the Chinese government.

In the view of the Expert Commission, China, and not Germany, is currently building up a lead market in the field of electromobility. Germany still has the chance to establish itself as a supplier of high-value electric vehicles, components, and information and communication technologies. To achieve this, it will be necessary to develop a co-ordinated strategy between German industry, government bodies and research organisations. The Expert Commission suggests that the National Platform for Electromobility (*Nationale Plattform Elektromobilität,* NPE) develop a suitable strategy for dealing with China.[382]