B 4 Artificial Intelligence

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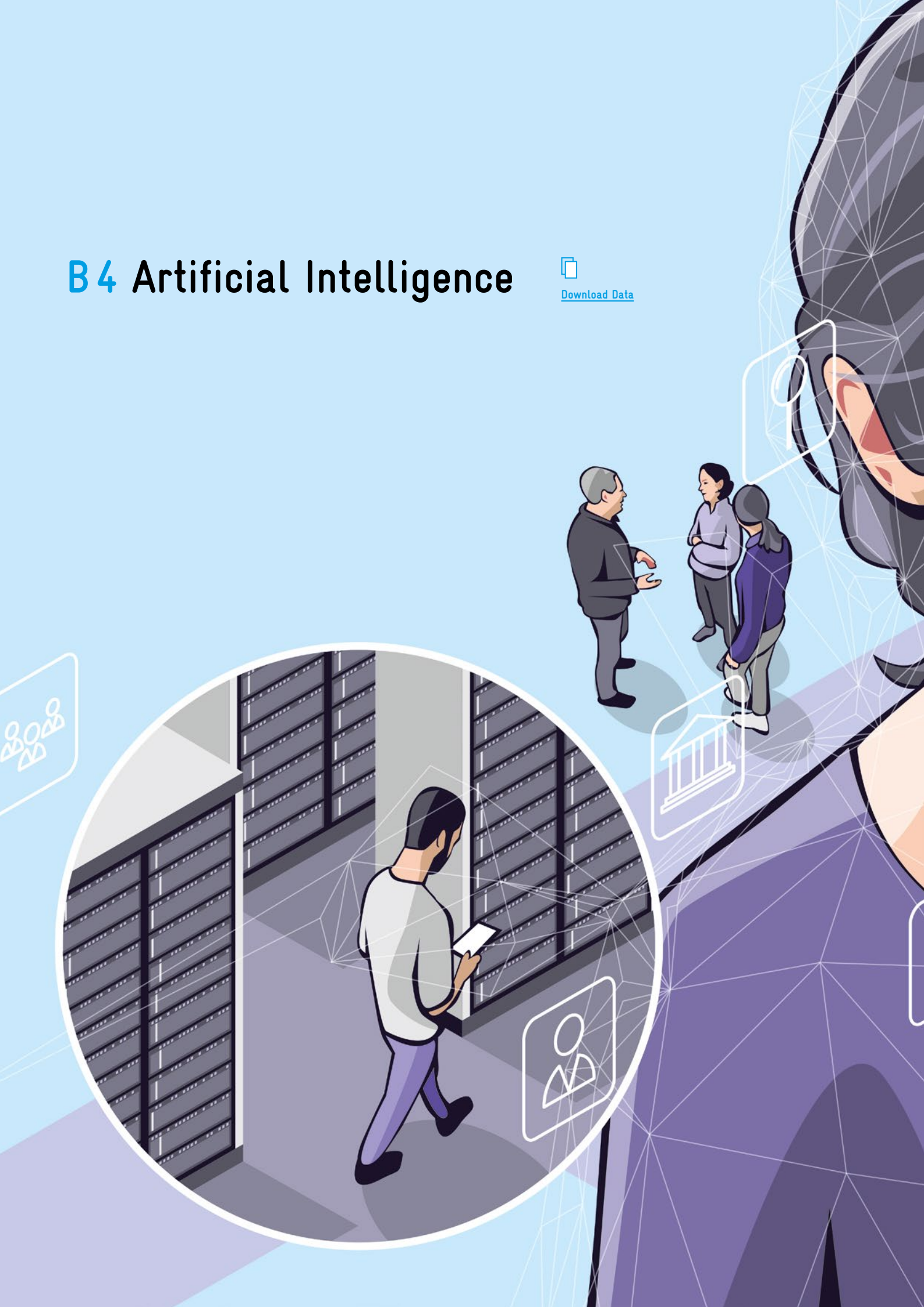

B 4 Artificial Intelligence

As a key enabling technology, artificial intelligence (AI) is characterized by highly dynamic development, has a broad range of applications such as in the automotive industry, financial services and medicine, and opens up a wide range of innovation and growth potential for user companies and industries.[423] AI therefore has enormous transformative potential that can lead to fundamental structural change in the economy and society. Due to these characteristics, AI is often compared to key enabling technologies such as the steam engine, electricity and the internet. In particular, generative AI, which makes it possible to generate texts, images and programme codes, for example, from so-called foundation models, is considered to have great potential for innovation.

The Commission of Experts has already addressed the topic of AI in previous annual reports and discussed the extent to which Germany can keep pace internationally in AI development. This question arises again in light of the rapid developments in the field of generative AI: new players are producing successful innovations, established players are adapting their strategies and questions of political support and regulation are being discussed on a wider political level.

Research and development (R&D) in the field of AI requires extensive data and computing capacities. Basic research is carried out both in research institutions and in businesses. The USA and China dominate in the field of AI, while Germany and the other countries of the European Union (EU 27) are falling behind in international comparison and run the risk of becoming technologically dependent when it comes to AI and thus no longer being able to actively shape technological development. Germany and Europe are therefore called upon to take measures to strengthen their technological sovereignty. This is also an important prerequisite for upholding European values such as non-discrimination, privacy and data protection in the development and use of AI.

To exploit the innovation and growth potential of AI, it needs to be used across the economy, i. e. in businesses of different sectors and sizes. Although many companies in Germany are planning to use AI, uncertainties and concerns regarding the maturity and reliability of AI still prevail.

To support an AI ecosystem, the Federal Government should continue to promote AI research and contribute to the development and expansion of the AI infrastructure in the form of data, computing capacity, venture capital and expertise. The AI Act should be adapted over time based on the knowledge and experience gained in regulatory practice in dialogue with actors from other economic and value areas. In doing so, a balance must be struck between legal certainty on the one hand and the creation and utilization of innovation potential on the other.

B 4-1 Dynamics of Technological Development

In recent years, science and industry have stepped up R&D activities in the field of AI overall. Favoured by the increasing availability of data and computing capacity, R&D activities have expanded enormously, particularly in the field of generative AI (cf. box B 4-1). This is reflected in an increase in the number of AI publications published in scientific

publications[424] and an increase in applications for transnational AI patents.[425]

Figures B 4-2 and B 4-3 use index analyses to show how the volume of AI-related scientific publications and the number of transnational patent applications have developed worldwide, both for AI as a whole and for generative AI. Transnational patent applications are patent applications filed with the European Patent Office or the World Intellectual Property Organization.[426] As no transnational patents were filed in the field of generative AI before 2013, the indices refer to the year 2013 and the patent figures for this base year are set to 100. The same procedure was followed for scientific publications and their number in 2013 is set equal to 100. The period under review begins in 2010. The current margin is 2022 for publications and 2020 for transnational patent applications.

The index value for AI publications was 78 in 2010 and rose eightfold to 630 by 2022. In the field of generative AI, the index value for publications was 80 in 2010 and increased by a factor of 52 to 4,130 by 2022.

The index value for transnational AI patents rose from 50 in 2010 to 820 in 2020 – a sixteen-fold increase. While there were no applications for transnational patents in the field of generative AI in 2010, the index value amounted to 4,420 in 2020.

Box B 4-1 Artificial Intelligence Terminology

Artificial intelligence
The term artificial intelligence is used to describe processes, algorithms and technological solutions that make it possible to transfer complex tasks previously carried out by humans to learning machines and software.[427]

Generative AI
Generative AI is a form of AI that is used to generate or edit content such as text as well as images, video, audio and computer code. This can be unimodal (e.g. text to text) or multimodal (e.g. text to image or image to text).

Machine learning
Machine learning (ML) aims to use learning algorithms and data to train complex models, which are then applied to new, potentially unknown data of the same type.[428]

Foundation model
Researchers at Stanford University coined the term foundation model for AI models that have been trained on a broad pool of data and can form the basis for the development of a variety of specific applications.[429] In German-speaking countries, such models are also known as *Grundlagenmodelle*.

Large language models and multimodal models
Large language models (LLM) are models that process and generate natural language. For example, they can compose and translate texts and answer questions. Multimodal models process and generate multiple modalities such as speech, audio and images. Large language models and multimodal models are forms of foundation models.

Parameters
Parameters are numerical values that are learnt by machine learning models during training.[430] The Luminous language model by Aleph Alpha,[431] for example, comprises between 13 and 70 billion parameters, depending on the variant.[432] The GPT-4 language model by OpenAI is said to comprise around 1.8 trillion parameters.[433]

Edge AI
With Edge AI, data is analyzed where it is generated rather than in the cloud.[434]

Federated learning
Federated learning is an ML process in which several units work together without directly exchanging data. A central server coordinates them.[435]

Fig. B 4-2 Scientific publications in the field of AI worldwide 2010–2022 as index values

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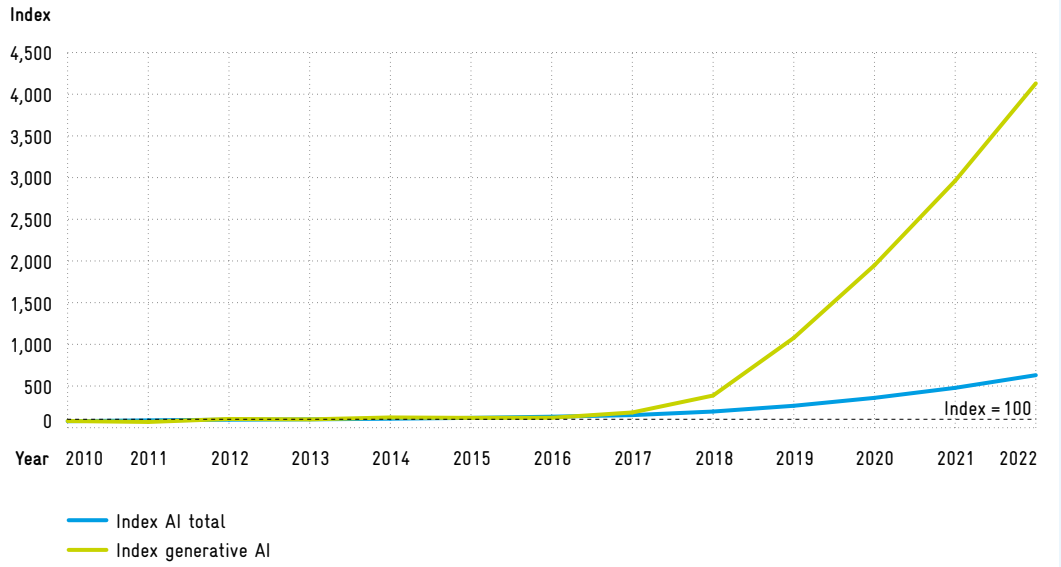

Index: 2013=100.
Legend: In 2020, 3.6 times as many scientific publications were published worldwide in the field of AI as in 2013; in the field of generative AI, 19.5 times as many scientific publications were published in that year as in 2013.
Source: Clarivate Web of Science Database (used database editions: SCIE, SSCI, AHCI, CPCI) in XML format, 2010–2022.
Own calculations within the context of the Competence Network for Bibliometrics (KB).

Fig. B 4-3 Transnational patent applications in the field of AI worldwide 2010–2020 as index values

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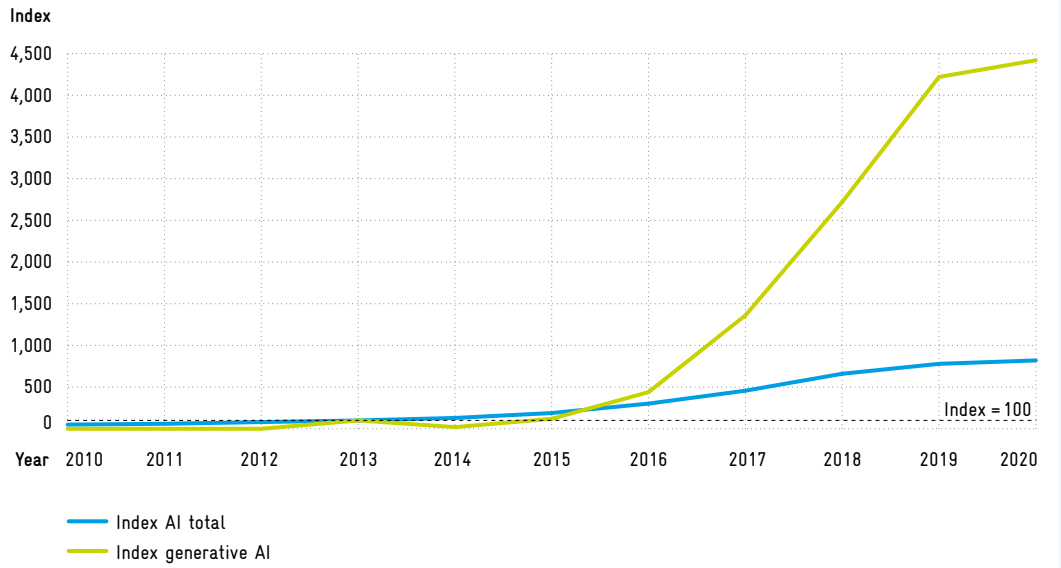

For the year 2020, an underreporting of patent applications cannot be ruled out, as it is possible that at the time of data collection in October 2023, it is possible that not all relevant patent applications from 2020 had already been published.
Index: 2013=100.
Legend: In 2020, 8.2 times as many patents were filed worldwide in the field of AI as in 2013; in the field of generative AI, 44.2 times as many patents were filed in that year as in 2013.
Source: PATSTAT. Own calculations.

B 4-2 Positioning of Germany and the EU in AI

The positioning of Germany and the EU in AI can be illustrated using publication and patent data. In the field of generative AI, it is also useful to look at data on machine learning models (ML models).

AI Publications: Germany and EU Far Behind China

In 2022, 147,700 AI-related scientific publications appeared worldwide, of which China accounted for 36.4 percent (cf. figure B 4-4).[436] Following far behind were the USA with 11.6 percent, India with 6.3 percent, South Korea with 3.5 percent and the UK with 3.4 percent. Germany only accounted for 2.7 percent of AI publications. The EU 27 together achieved a share of 14.5 percent.

While China was able to increase its share by 22.9 percentage points between 2010 and 2022, the USA's share fell by 5.3 percentage points. Germany recorded a decline of 1.4 percentage points. The share of the EU 27, which was still higher than China's in 2010, fell significantly by 11.8 percentage points between 2010 and 2022.[437]

In the field of generative AI, authors from Chinese organizations accounted for 40.3 percent of the scientific publications published in the period 2017 to 2022 (cf. figure B 4-5). The USA followed with a share of 14.4 percent. This means that more than half of the publications in this field came from China and the USA. Germany's share, as with AI publications overall, was only 2.7 percent. Authors from organizations from the EU 27 wrote 11.8 percent of the publications.

Most AI-related scientific publications can be traced back to authors working at tertiary education institutions.[438] However, there are also areas within AI where companies are researching and publishing very intensively and which are closely linked to generative AI models. For example, Microsoft, Google, the Alibaba Group and Amazon were among the ten organizations that published the most papers in scientific journals in the field of natural language processing in 2021.[439] In the field of speech recognition, Microsoft, Google, Tencent and Amazon were among the top ten publishing organizations.[440] Neither German businesses nor companies from the EU were among the ten organizations with the most scientific publications in either field.

AI Patent Applications: German and EU Shares Declining

The data on transnational AI patents filed in 2020 shows that the majority of inventors were based in China and the USA, with shares of 28.5 and 26.6 percent respectively (cf. figure B 4-6).[441] Germany had a share of 6.5 percent. At 16.2 percent, the share of the EU 27 was below that of China and the USA.

Between 2010 and 2020, China's share rose by 25 percentage points, while the USA's share fell by 6.7 percentage points. Germany's share fell by 4.1 percentage points. The share of the EU 27 also declined, falling by 9 percentage points in the period under review.[442]

In the field of generative AI, the USA led the field with 32.9 percent of all transnational patents filed worldwide between 2017 and 2020, followed by China with 24.5 percent of applications (cf. figure B 4-7). Germany accounted for 6.1 percent and the EU 27 for a total of 15.3 percent of transnational patents filed in the field of generative AI.

As in other fields of technology, the majority of patents in AI are filed by companies. The 20 organizations that filed the most transnational AI patents between 2010 and 2020 include five Japanese and five US companies, four Chinese companies, two German and two South Korean companies and one Finnish and one Dutch company (cf. figure B 4-8). The two German companies are Siemens and Bosch.

With a comparatively small number of patents, the picture in the field of generative AI is similar to that of AI as a whole (cf. figure B 4-9). Seven US companies, four Chinese companies and one Chinese research institution, two German and two Japanese companies as well as one South Korean, one Dutch, one Swedish and one Finnish company are among the 20 organizations that filed the most transnational patents in this field between 2010 and 2020. The two German companies are again Siemens and Bosch, which are also among the top organizations for AI patents overall.

Fig. B 4-4 Percentage of selected countries in scientific publications in the field of AI 2010–2022

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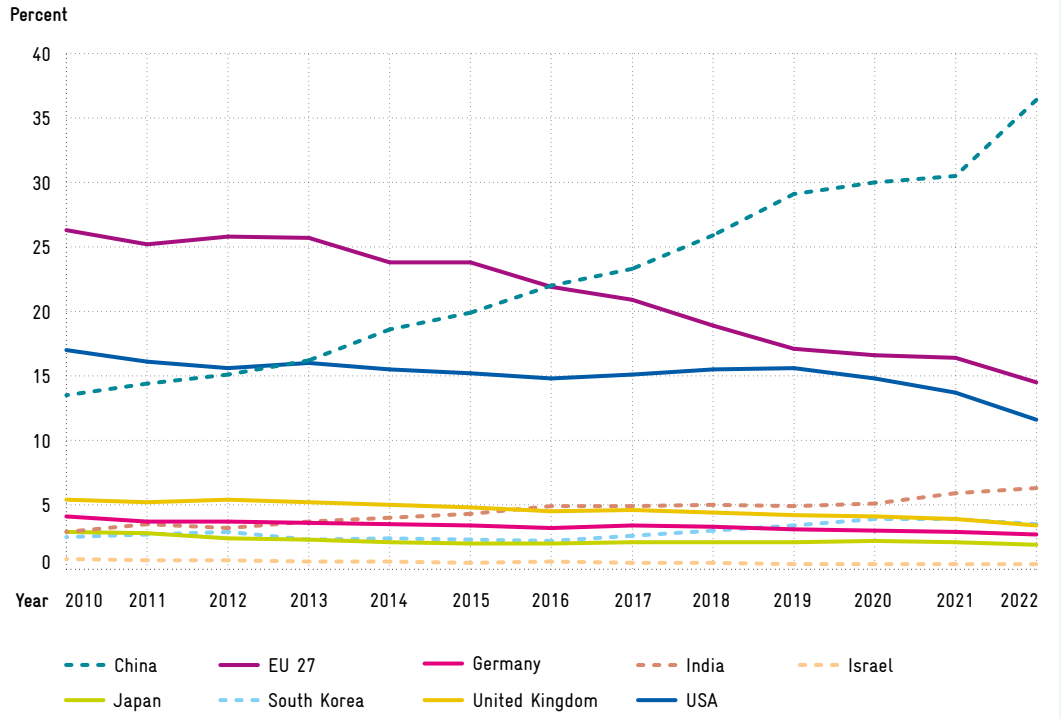

Legend: China's share of scientific publications in the field of AI increased from 13.5 percent in 2010 to 36.4 percent in 2022.
Source: Clarivate Web of Science Database (used database editions: SCIE, SSCI, AHCI, CPCI) in XML format, 2010–2022.
Own calculations within the context of the Competence Network for Bibliometrics (KB). Fractional counting.

Fig. B 4-5 Percentage of selected countries in scientific publications in the field of generative AI 2017–2022

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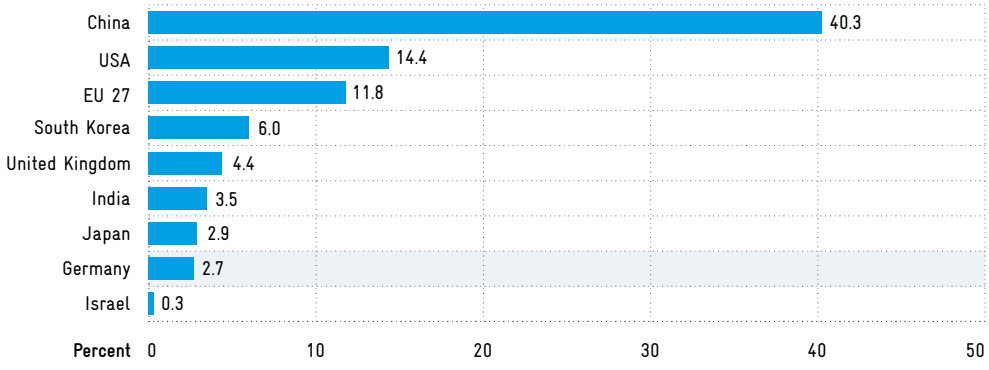

Legend: In the period from 2017 to 2022, India's share of scientific publications in the field of generative AI was 3.5 percent.
Source: Clarivate Web of Science Database (used database editions: SCIE, SSCI, AHCI, CPCI) in XML format, 2017–2022.
Own calculations within the context of the Competence Network for Bibliometrics (KB). Fractional counting.

Fig. B 4-6 Percentage of selected countries in transnational patent applications in the field of AI 2010–2020

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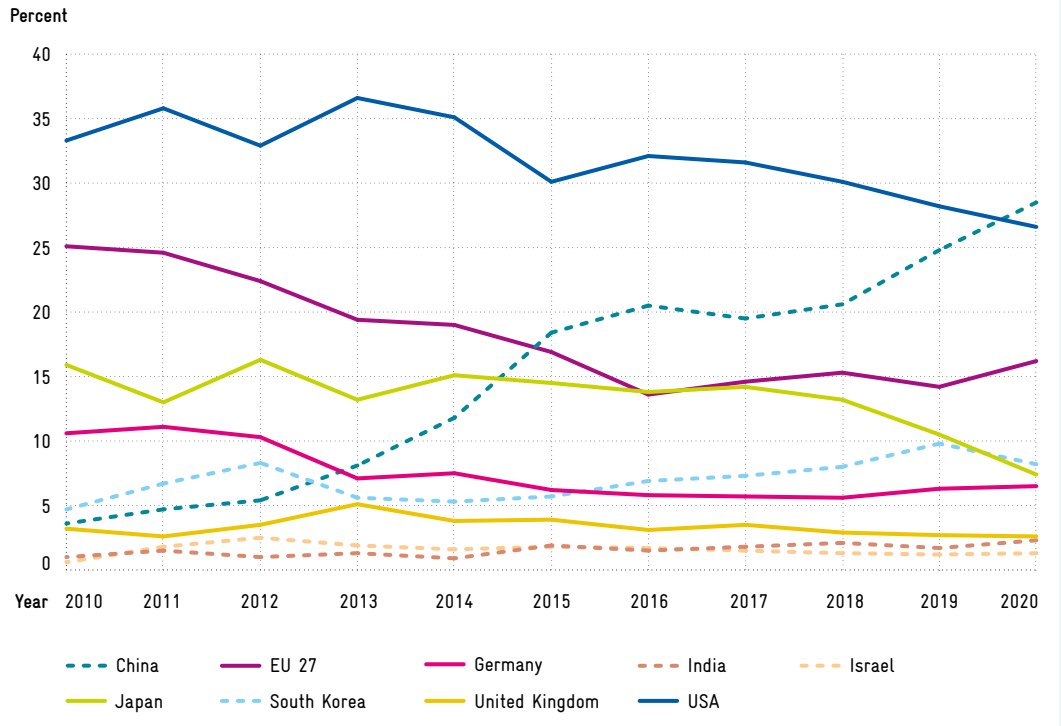

Legend: In 2019, the USA accounted for 28.2 percent of transnational patent applications in the field of AI.
Source: PATSTAT. Own calculations. Fractional counting.

Fig. B 4-7 Percentage of selected countries in transnational patent applications in the field of generative AI 2017–2020

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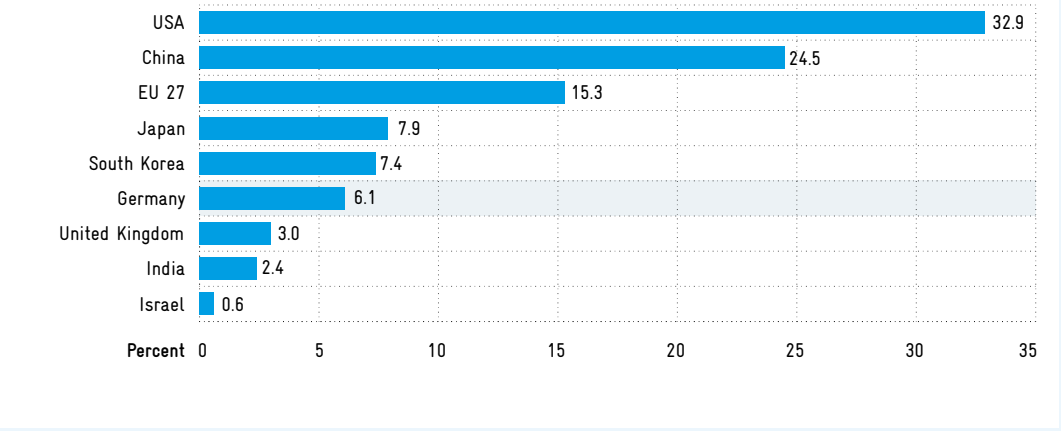

Legend: The EU 27 accounted for 15.3 percent of transnational patent applications in the field of AI between 2017 and 2020.
Source: PATSTAT. Own calculations. Fractional counting.

Fig. B 4-8 Transnational patent applications in the field of AI by filing organisations and their headquarters 2010–2020

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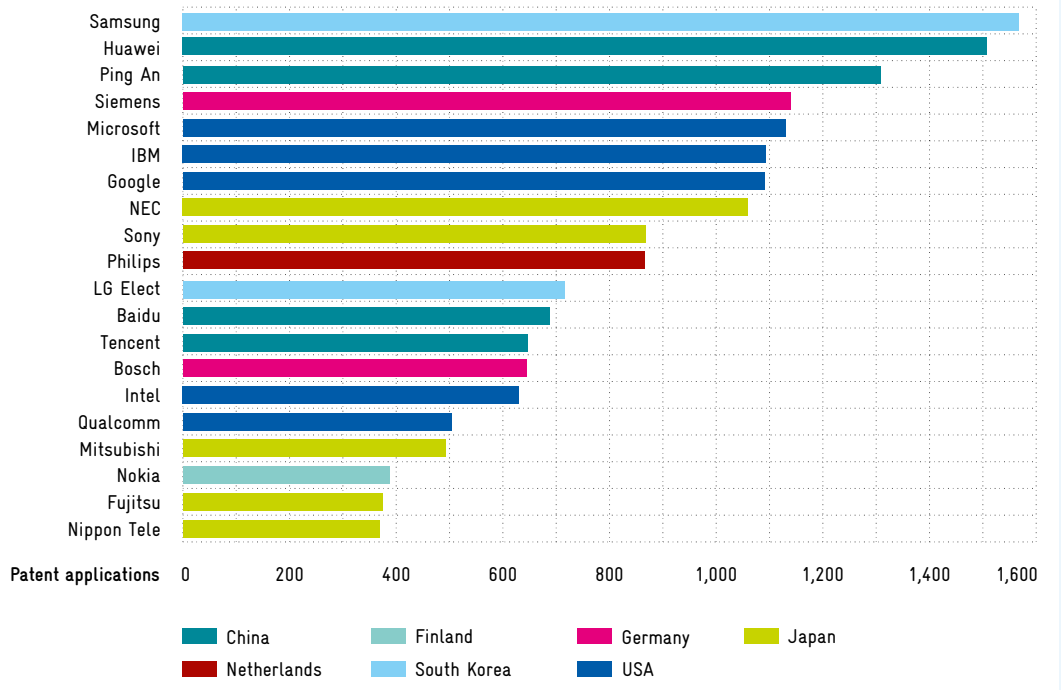

Legend: The Chinese company Huawei registered 1,508 AI patents in the period under review.
Source: PATSTAT. Own calculations. Fractional counting.

AI Models: Germany and EU Only at the Beginning

Not all innovations and further developments in the field of AI are documented in publications or patents. For example, there are no scientific publications or patents on the model architecture of GPT-4, OpenAI's large language model. To assess the international competitive situation, particularly in the field of generative AI, it is therefore useful to consider not only publications and transnational patents but also development leaps in the field of ML models (cf. box B 4-1).

Based on data from Epoch AI, the Artificial Intelligence Index Report 2023 of the Stanford Institute for Human-Centered Artificial Intelligence (HAI) recorded the publication of 38 particularly significant ML models in 2022, 32 of which came from the business sector.[443] Until 2014, the scientific sector still accounted for the largest share of ML models. Over time, the size, training effort and thus the costs of such ML models have steadily increased[444] and now amount to tens of millions of US$.[445] Tertiary education institutions and publicly funded non-university research institutions can reach their budget limits more quickly than large IT companies when developing such models. Start-ups too often lack the necessary financial resources for this.

Among the major ML models, large language models and multimodal models are gaining in relevance, as they are foundation models that can be adapted to a variety of subsequent tasks. The number of countries involved in the development of such models has increased over time. According to the Artificial Intelligence Index Report 2023, all major language models and multimodal models were developed in the USA in 2019.[446] Of the major language models and multimodal models published in 2022, just over half still originated from the USA (54.2 percent). The UK (21.9 percent), China (8.0 percent), Canada (6.3 percent), Israel (5.8 percent), Germany (3.1 percent) and India (0.9 percent) were also involved

Fig. B 4-9 Transnational patent applications in the field of generative AI by filing organisations and their headquarters 2010–2020

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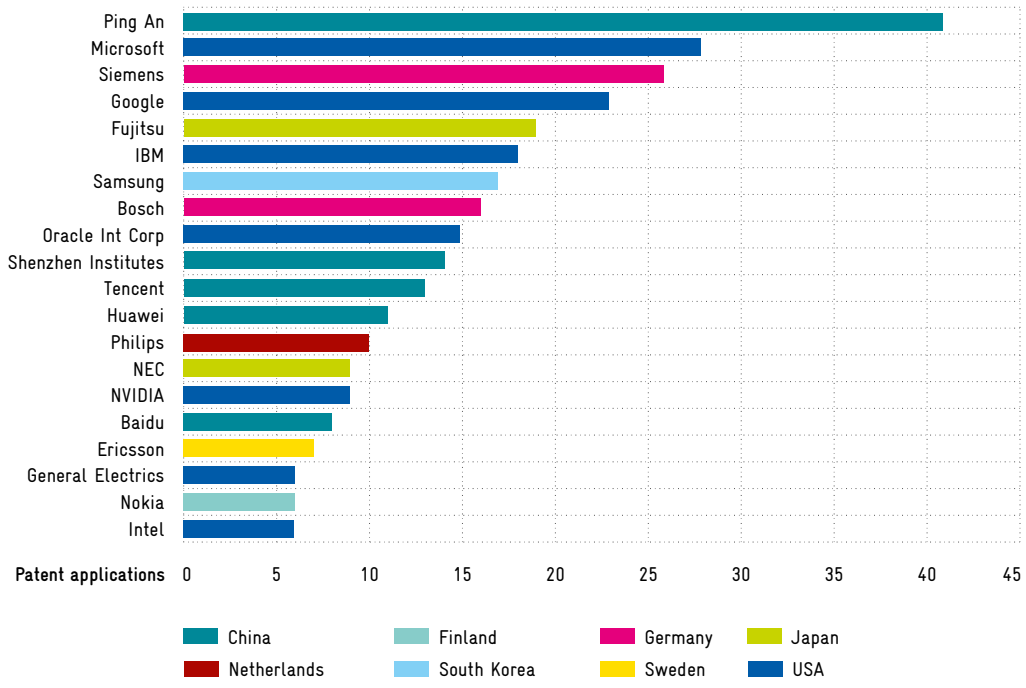

Legend: The US company Microsoft registered 28 patents in the field of generative AI during the period under review.
Source: PATSTAT. Own calculations. Fractional counting.

in the development of large language models and multimodal models. Canada, Germany and India contributed to large-scale language and multimodal models for the first time in 2022 with Stable Diffusion, GPT-NeoX-20B and Imagen.[447] In 2023, that is, outside the observation period of the Artificial Intelligence Index Report 2023, further countries followed suit. For example, the Technology Innovation Institute in the United Arab Emirates published Falcon 40B and Falcon 180B and the French start-up Mistral AI published Mistral 7b v0.1 as large language models.[448]

B 4-3 AI Utilization a Driver of Innovation and Growth

To exploit the innovation and growth potential of a new technology, this technology must be used across the economy. In contrast to key enabling technologies such as the steam engine and electricity, the spread of information and communication technologies has not yet led to major productivity boosts. There are various explanations for this so-called productivity puzzle.[449] The time factor plays an important role here. It can be assumed that the diffusion of a key enabling technology such as artificial intelligence will take a long time and only arrive unevenly in the various sectors.[450] There are activities, particularly of a physical nature, that cannot be supported or replaced by AI. In addition, application-specific innovations and complementary investments, for example in interface technologies, work organization and human capital, are required in order to exploit the productivity potential of AI.[451] Econometric analyses for Germany show that companies that use AI are both more innovative and more productive, although this does not yet prove a causal effect of AI.[452]

A representative survey conducted on behalf of the Commission of Experts shows that in 2023, 10 percent of companies in the manufacturing sector and 30 percent of companies in the information economy in Germany have used AI (cf. figure B 4-10). However, these results do not allow any conclusions to be drawn about the degree of AI utilization in

Fig. B 4-10 Percentage of AI use in companies in Germany by company size in 2023

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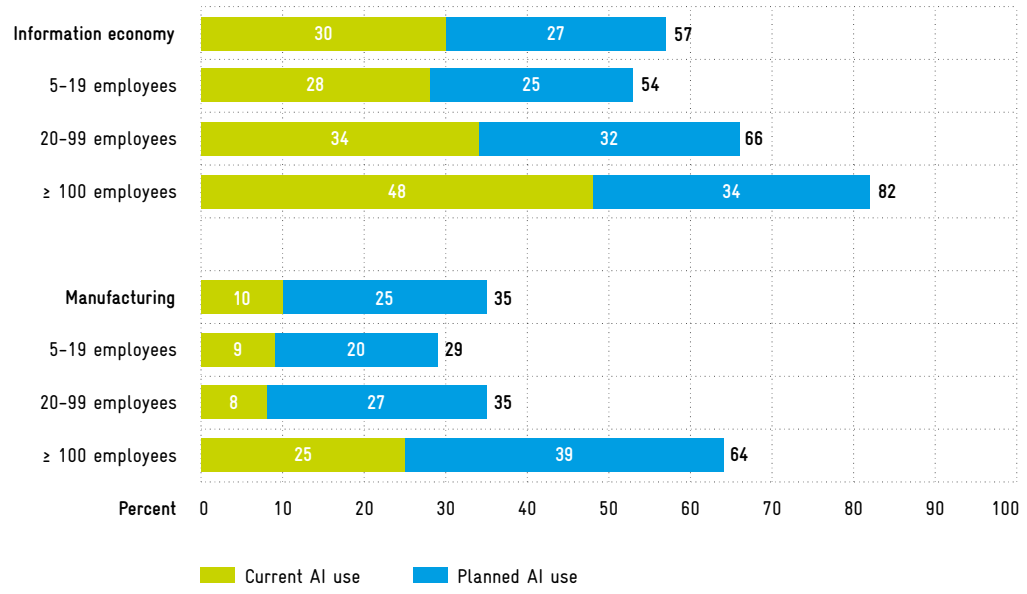

The companies were asked about the use of AI in at least one of the following areas: "As part of own products/services", "In the improvement/development of new products/services", "In the improvement/development of new processes", "In other areas/for other purposes". Deviations in the total are possible due to rounding.
Legend: In the information economy, 30 percent of companies stated that they use AI in at least one of the areas surveyed. In addition, 27 percent of companies in the information economy planned to use AI in the future.
Source: ZEW Konjunkturumfrage Informationswirtschaft Q3 2023.

companies.[453] A further 27 percent of companies in the information economy and 25 percent of companies in the manufacturing sector planned to use AI in the future. The percentage of companies using or planning to use AI increases with the size of the company.[454]

The main barriers to the utilization of AI in both the information economy and the manufacturing sector were a lack of time or manpower (68 and 72 percent), uncertainty about the expected benefits (64 and 68 percent), concerns about the maturity or reliability of AI (60 and 56 percent) and a lack of knowledge and expertise within the company (53 and 60 percent) (cf. figure B 4-11). Companies in the manufacturing sector cited a lack of skilled labour being a barrier to the utilization of AI significantly more often than companies in the information economy (59 versus 50 percent).

Only 15 percent of companies in the information economy and 6 percent of companies in the manufacturing sector rated the international competitiveness of their own company in the field of AI as high or very high (cf. figure B 4-12). They were slightly more likely to attribute a very high or high level of competitiveness in the field of AI to companies in their own sector (around 21 and 7 percent) and to companies in Germany as a whole (around 24 and 25 percent).

Another result of the survey is that 32 percent of companies in the information economy and 26 percent of companies in the manufacturing sector expected the increasing spread of AI to lead to increasing dependence on non-European AI providers.

The Commission of Experts states that a relatively large number of companies are currently planning to use AI. However, as the barriers to AI utilization identified by the companies show, concerns and uncertainty prevail. There is also a lack of AI expertise in companies.

Fig. B 4-11 Barriers to the use of AI in companies in Germany in 2023 in percent

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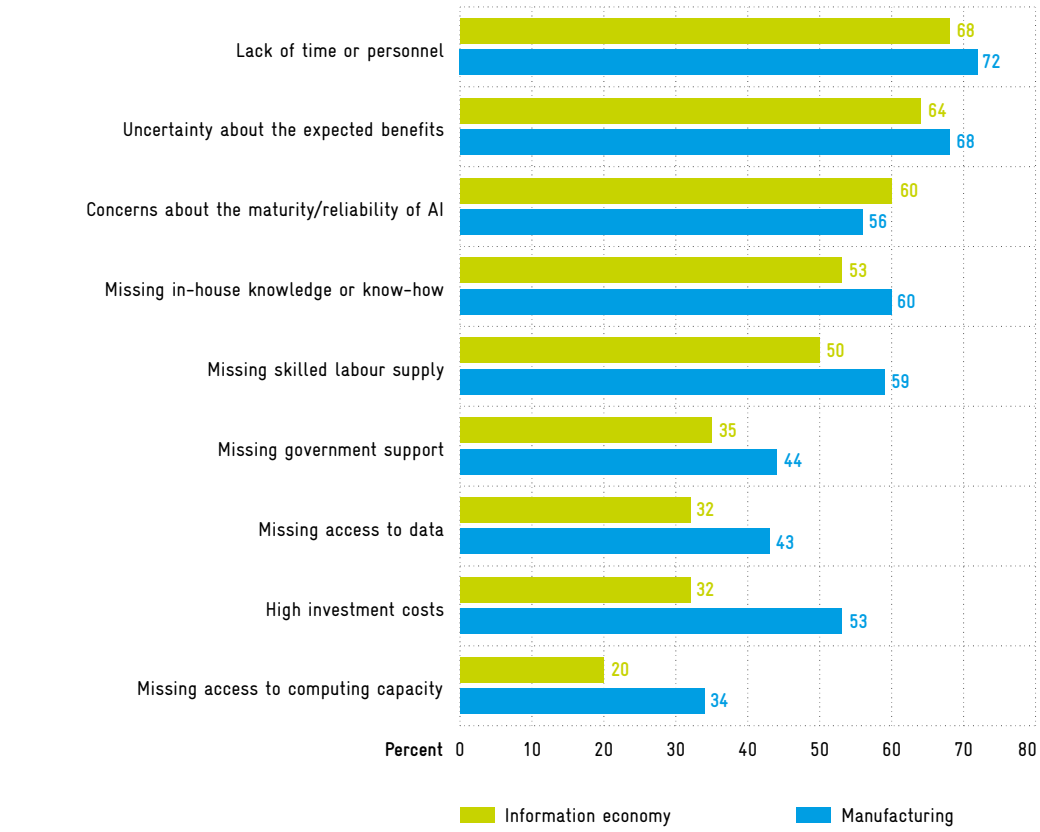

Legend: 68 percent of companies in the information economy stated that a lack of time or personnel capacity made the use of AI more difficult.
Source: ZEW Konjunkturumfrage Informationswirtschaft Q3 2023.

Fig. B 4-12 Assessment of international competitiveness in the field of AI in 2023 in percent

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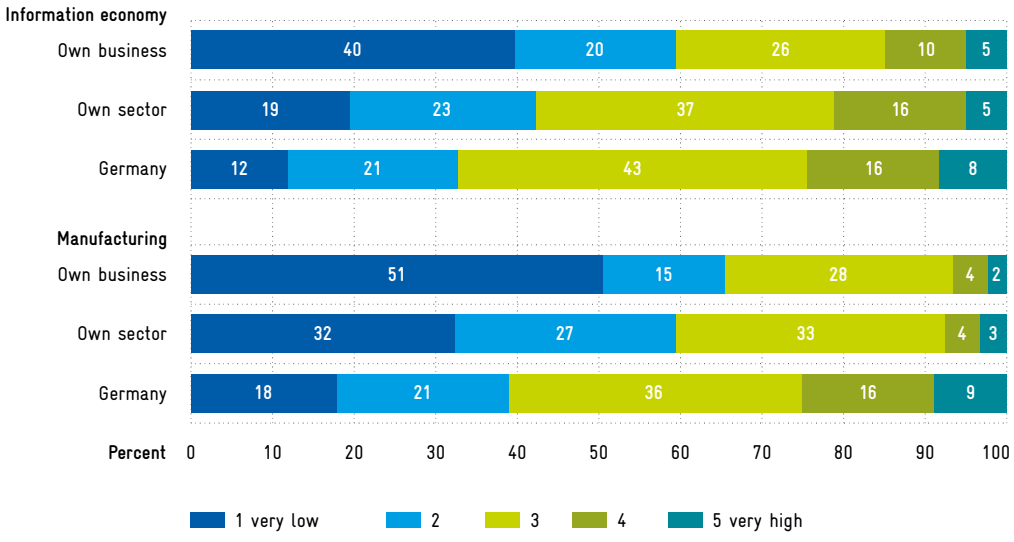


Deviations in the total are possible due to rounding.
Legend: 5 percent of companies in the information economy rated the international competitiveness of their own business in the field of AI as very high.
Source: ZEW Konjunkturumfrage Informationswirtschaft Q3 2023.

B 4-4 Technological Sovereignty and European Values

AI is a key enabling technology that will have a decisive impact on technological and economic development in the coming years.[455] AI is characterized by its breadth of application in a variety of technologies and industries, very often without an equivalent technological alternative. The high level of dynamism in R&D in the field of AI underlines the fact that there is still enormous potential for performance improvements in AI itself as well as in its areas of application, some of which are new.

As a key enabling technology, AI is highly relevant for future innovation and growth potential in Germany and Europe, as well as for the opportunities to actively shape economic and social transformation processes and thus contribute to solving grand societal challenges.[456] To leverage this potential, Germany and Europe must demonstrate a high degree of technological sovereignty.

Technological sovereignty in the field of AI presupposes that Germany and Europe can maintain and further develop AI technologies themselves and participate in their standardization or have the ability to obtain and use these technologies without being unilaterally dependent on other economic areas. Mastering the technology is therefore an essential prerequisite for technological sovereignty, which requires corresponding competences in dealing with AI.[457]

The Commission of Experts is concerned that Germany and the EU 27 continue to fall behind in international comparison, both in the publication of scientific AI papers and in the registration of AI patents. Germany and Europe are also not international leaders in the development of significant ML models. Overall, there is a risk of losing technological sovereignty.[458]

AI applications can be associated with risks. For example, targeted misinformation can influence voting decisions or training data can reproduce prejudices that lead to discriminatory decisions. In developing and using AI, the European Union (EU) pursues a people-centred approach, the protection of EU values and fundamental rights such as non-discrimination, privacy and data protection as well as the sustainable and efficient use of resources.[459] Technological sovereignty is therefore also a prerequisite for developing AI models in one's own cultural context and thus ensuring that they are in line with European values.

B 4-5 Open-Source Models

Foundation models are very important for the development of AI applications. This means that developers of applications that are based on foundation models must either have their own foundation models or have access to the foundation models of others. If this is not the case in Germany and Europe, technological sovereignty is not guaranteed.

The development of AI foundation models such as the large language models requires a powerful computing infrastructure, which currently is mainly available via the large cloud providers. The related offerings are limited in Germany and Europe. It is therefore to be expected that, due to the ongoing scaling of foundation models, actors in science and industry will increasingly rely on non-European cloud providers, thereby reinforcing the gatekeeper role of these companies.[460]

The technological sovereignty of Germany and Europe can be weakened if there is a market concentration of non-European providers through vertical company integration[461] in the case of foundation models and applications based on them. In addition, European values may be jeopardized if foundation models lead to distorted results in applications that are based on these models and this cannot be remedied.

Open source is seen as very important for boosting technological sovereignty and for an AI that is in line with European values.[462] Foundation models can be available as closed- or open-source models. Unlike closed-source models, open-source models disclose the codes, training data and model architecture, with varying degrees of openness.[463] Some foundation models from commercial providers also have a high degree of openness.[464] However, in some cases, the transition to new versions involves a change from open- to closed-source models.[465] For example, OpenAI published its GPT-2 XL foundation model as an open-source model, but GPT-3 and subsequent versions as closed-source models.[466]

Commercial enterprises are incentivized to develop foundation models if this results in opportunities to

generate revenue. This is the case if the companies enable external users, for example in connection with cloud services, to develop applications based on the foundation models for a fee. Revenue opportunities can also arise with open-source foundation models if, based on self-developed open-source models, proprietary AI applications are offered that are either subject to a fee or generate advertising revenue. Companies additionally benefit from the fact that external parties can participate in improving the model. It is not yet possible to predict how the market for foundation models and AI applications will develop.

Open-source models can intensify competition and offer more opportunities for innovation than closed-source models, as they are generally more adaptable.[467] In addition, actors from science and industry, especially start-ups and SMEs, can benefit from the relatively low costs of open-source utilization and use existing open-source models to innovate on a domain-specific basis and increase productivity.[468] This increases competition and the diversity of offerings and thus prevents monopolization tendencies. In addition, open-source models have the advantage that programming errors or potential distortions that arise when analyzing data can be identified and rectified more quickly. This is conducive to the transparency and reliability of AI models.[469]

Due to the aforementioned advantages, the (collaborative) development of large-scale open-source models in Germany and Europe can contribute to increasing technological sovereignty and to the utilization of AI in line with European values. Building on open-source models, German and European science and industry can secure access to AI without having to rely on the few large non-European providers. In addition, in-house AI capabilities can be further developed, which is essential for mastering a technology. This can make a significant contribution to catching up in the technological competition.[470]

The creation of foundation models is associated with high costs, particularly for computing capacity and training data (cf. section B 4-6). These costs are too high to be borne by an open-source developer community alone. It is also necessary to provide the required security architecture. Both factors represent a challenge for the development of foundation models based on open source, which are not initiated and provided by large companies but by developer communities. Political support could help to incentivize the development of foundation models based on open source.

B 4-6 AI Innovation Ecosystem in Germany

To prevent falling further behind in the development and application of AI, Germany and Europe need to catch up in terms of scope as well as drive forward specializations and achieve technological leadership in these areas. Generative AI in particular, as a very young variant of AI, is still in the early stages of its technology life cycle. With the development of a powerful AI ecosystem, Germany and the EU still have opportunities to play a leading role in international technology development with innovations in both generative AI and AI applications. However, large AI companies, such as those in the USA and China, are not available. Germany and Europe therefore need strong AI innovation ecosystems.[471] An AI ecosystem comprises a large number of components. These include a science system with a network across Europe, AI expertise, an efficient AI infrastructure and venture capital.

AI Research Broadly Positioned in the Science System

AI research is conducted at many German tertiary education institutions and non-university research institutions. The AI map of Plattform Lernende Systeme, Germany's platform for artificial intelligence, lists 153 higher education institutions and 82 non-university research institutions that conduct research on AI topics.[472]

The Federal Government is funding the German Research Center for Artificial Intelligence (DFKI) as well as five Centres of Excellence for AI Research based at tertiary education institutions, namely the Berlin Institute for the Foundations of Learning and Data (BIFOLD), the Munich Center for Machine Learning (MCML), the LAMARR Institute for Machine Learning and Artificial Intelligence (formerly Kompetenzzentrum Maschinelles Lernen Rhein-Ruhr – ML2R), the Center for Scalable Data Analytics and Artificial Intelligence (ScaDS.AI) and the Tübingen AI Center.[473] These latter five Centres of Excellence for AI Research are amalgamations of tertiary education institutions and non-university

Box B 4-13 Examples of German and European Initiatives in the Field of Open Source

Silicon Economy (Fraunhofer-Institute for Material Flow and Logistics)
Silicon Economy is a digital ecosystem based on open source and AI that enables the automated negotiation, scheduling and control of commodity flows and aims to create new digital business models. It promotes the integration and networking of infrastructures, including secure data rooms and cloud infrastructures. The focus is on the development of automation and autonomization services for logistics and complete supply chains.[474]

Sovereign Tech Fund
The Sovereign Tech Fund is dedicated to sustainably strengthening the open-source ecosystem and focuses on security, stability and technological diversity. It promotes and invests in open, free and trustworthy digital infrastructures that serve as a cornerstone for cross-sector digitalization in order to boost digital sovereignty and increase the resilience of the open-source ecosystem.[475]

OpenWebSearch.EU
The EU-funded OpenWeb-Search.EU project unites 14 European research and computing centres to create an open infrastructure for web search. The aim is to reduce the dominance of large tech companies in the web search sector by promoting a free, people-centred search engine market in order to strengthen Europe's digital sovereignty and capacity for innovation.[476]

OpenGPT-X
OpenGPT-X is a European R&D project funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK). It aims to develop and provide an AI language model that meets the specific needs, values and data protection requirements in Europe. The technical basis for this language model is provided by the European Gaia-X infrastructure. The founding members of OpenGPT-X are companies, research institutes and media organizations.[477]

research institutions. The Centres of Excellence for AI Research are intended to enable scientific breakthroughs, accelerate the transfer of knowledge and technology and train AI specialists. Together they form the Network of German Centres of Excellence for AI Research. [478]

The European Laboratory for Learning and Intelligent Systems (ELLIS) Society was launched in 2018 as a European initiative for research excellence in the field of machine learning and artificial intelligence. ELLIS is building a network of European AI research locations with the aim of connecting cutting-edge research and creating an internationally competitive AI ecosystem. These locations are either established at existing AI research institutions by way of so-called ELLIS Units or are newly founded as ELLIS Institutes.[479]

Another European initiative launched in 2018 is the Confederation of Laboratories for Artificial Intelligence Research in Europe (CLAIRE).[480] CLAIRE is an alliance of artificial intelligence research laboratories that seek to promote European excellence in AI research and innovation.[481]

High Demand for AI Skills

The development and application of AI technologies requires qualified professionals.

AI professors are important actors in the AI ecosystem as they conduct AI research and also train professionals with AI skills. As part of the AI Strategy launched in 2018, it was announced that at least 100 additional AI professorships would be created. According to the Federal Government, 150 additional AI professorships have since been established through various BMBF measures to support the Länder,[482] of which 54 have been filled by scientists from abroad.[483]

The BMBF is currently funding 42 AI junior research groups.[484] In addition, there are Zuse Schools of Excellence in AI,[485] the International Future Labs for Artificial Intelligence[486] and the KI-Nachwuchs@FH

funding guideline as part of the Research at Universities of Applied Sciences programme.[487]

The AI map of the Plattform Lernende Systeme lists 41 designated AI degree courses, of which 14 are bachelor's and 27 master's degree courses.[488] There are also 103 computer science degree courses with an AI focus and 21 other degree courses with AI content.

To bring AI into widespread use, AI skills are required in many professions. The penetration rate of AI skills is an indicator created by LinkedIn that measures the prevalence of AI-related skills in a profession.[489] The relative penetration rate of AI skills indicates how prevalent AI skills are in different professions in a country in comparison to the global average.[490]

In the period from 2015 to 2022, the relative penetration rate of AI skills in Germany was 1.72 (cf. figure B 4-14). This means that the average penetration of AI skills in Germany was 1.72 times higher than the global average. This put Germany in third place among the comparison countries.[491] Only in India and the USA was the relative penetration rate of AI skills higher at 3.23 and 2.23. Nonetheless, many businesses perceive a lack of skilled workers as a barrier to the utilization of AI. The survey on behalf of the Commission of Experts shows that this applies to 50 percent of companies in the information economy and 59 percent of companies in the manufacturing sector (cf. figure B 4-11).

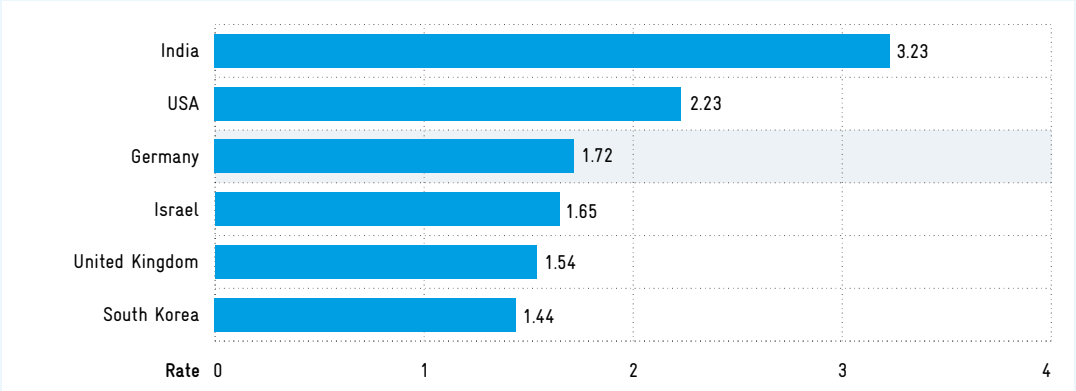
An analysis of online job advertisements in Germany reveals[492] that the number of job vacancies in the field of AI increased steadily from 2019 to 2022, from 11,056 in the first quarter of 2019 to 19,546 in the first quarter of 2022. In the first quarter of 2023, the number of job vacancies was 16,387, lower than in the previous year. This slight decline followed the overall trend in job vacancies.[493] The largest share of open AI positions, 72 percent, were job advertisements in the fields of business intelligence and big data. Following at considerably lower percentages were the fields of consulting (20 percent), research and science (13 percent), robotics (12 percent), assisted driving (11 percent), image processing (7 percent) and speech processing (6 percent).

Data and Computing Capacity Limiting Factors

Computing capacity and data are required for the development of both foundation models and AI applications.

AI applications come with specific hardware requirements. Graphic processing units (GPUs) are particularly suitable for their calculations.[494] The availability of computing capacity for training AI foundation models is currently a limiting factor.

Fig. B 4-14 Relative penetration rate of AI skills for selected countries 2015–2022



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The penetration rate of AI skills measures the prevalence of various AI-related skills in different occupations.
The relative penetration rate of AI skills for a specific country indicates the sum of the penetration rates of the individual AI skills across the various occupations as a proportion of the global average in the respective same occupation.
Legend: In the period from 2015 to 2022, the average penetration of AI skills in South Korea was 1.44 times higher than the global average.
Source: Maslej et al. (2023: 182) based on LinkedIn data.

Researchers and businesses that have access to powerful computing infrastructure have an advantage here.[495] For example, OpenAI uses Microsoft's cloud infrastructure for its calculations and has licensed its foundation model exclusively to Microsoft.[496]

In its AI Action Plan, the BMBF formulates the goals of providing an internationally more competitive high-performance computing infrastructure, significantly increasing the number of AI users on German and European HPC systems and specifically enabling the research and development of a significant proportion of large AI models in Germany and Europe.[497] The expansion of computing infrastructure is a prerequisite for further research and application in the field of AI.

Training large language models or multimodal models requires large amounts of training data such as content from the internet or books.[498] Specialized foundation models, for instance in the medical field, require specialized data. Data are also required to adapt pre-trained foundation models to specific applications. This could be the data of an organization that is developing or customizing an AI application for its own use. Equally, it can be data that start-ups and SMEs use to develop applications, which they then sell.

In an international comparison, German and European actors may find themselves at a competitive disadvantage when developing AI models or applications if existing data are not available or data use is regulated more restrictively than in other countries, for example, regarding data privacy and copyright. This can weaken technological sovereignty. In view of the protection of European values, restrictive management of data use has a double edge. On the one hand, it helps to protect the rights of data subjects. On the other hand, it can lead to AI models from non-European competitors being used in Germany and Europe that were not developed in accordance with European values.

The Commission of Experts has repeatedly pointed out that data in Germany must be made more readily available. The Federal Government and the legislature have already introduced measures such as the establishment of a data institute and the passing of the Health Data Use Act to improve the situation.[499] Gaia-X, Catena-X and Manufacturing-X could also make a contribution to the development and expansion of an AI ecosystem.[500] In its AI Action Plan, the BMBF announces that it will increase data availability in science with the National Research Data Infrastructure (Nationale Forschungsdateninfrastruktur, NFDI), the European Open Science Cloud (EOSC) and other support measures, for example, in the health sector, and that by introducing a Research Data Act it will improve the findability, access and linkability of data.[501] In June 2023, the European Data Governance Act came into force,[502] based on which data trustee models can be developed.

AI Venture Capital Investment Low

It is often AI start-ups that develop new ideas and business models. For them, venture capital is an important source of financing to drive technology development and growth.

Between 2021 and 2023, an annual average of US$79.6 billion in venture capital was invested in US-American AI start-ups (cf. figure B 4-15). This far exceeds venture capital investments in AI made in China (US$28.5 billion) and the EU 27 (US$12.4 billion) over the same period. Germany accounted for 29 percent of venture capital investments in the EU 27 (US$3.6 billion).

According to ZEW, the number of economically active AI start-ups in Germany increased significantly within 14 years – from around 1,200 in 2007 to around 3,000 in 2021.[503] A slight decrease was observed in 2022 and 2023.[504] In the ZEW's AI start-up survey 2023, 32 percent stated they had venture capital.[505] The appliedAI initiative estimates that, given a narrower definition of AI start-ups based on data, talent, AI methods, scalability and overall quality, the AI ecosystem in Germany included around 500 relevant AI start-ups in 2023.

B 4-7 AI Policy and Regulation

Interdepartmental Coordination on Generative AI Should Be Expanded

The Federal Government aims to strengthen the AI ecosystem in Germany with a number of strategies (cf. box A 2-16). The Federal Government's AI Strategy was adopted in 2018. Generative AI was not yet the focus of this or the subsequent update. The AI Action Plan published in 2023 now takes current developments such as generative AI into account and identifies key areas of action. However,

Fig. B 4-15 Average annual venture capital investment in AI for selected countries 2021–2023 in US$ millions

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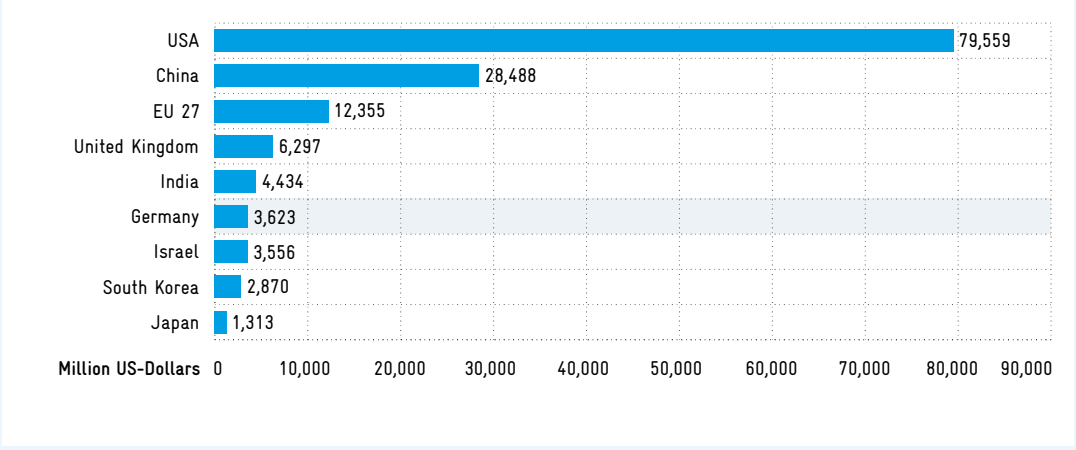

The data for 2023 included in the 2021–2023 mean value is an estimate.
Legend: In the USA, an annual average of around US$79.6 billion in venture capital was invested in AI between 2021 and 2023.
Source: OECD.AI (accessed on 27 Nov. 2023) based on data by Preqin. Own calculations.

it refers exclusively to the field of responsibility of the BMBF and therefore cannot do justice to the broad scope of application of AI as a key enabling technology. The Federal Government has not yet undertaken an interdepartmental update or redesign of the AI Strategy.

EU AI Act Proposed as World's First AI Law

The EU is aiming to pass the first-ever legal framework on AI – the Artificial Intelligence Act (AI Act). In December 2023, the European Council and the EU Parliament reached a provisional agreement on regulating AI. This still needs to be formally decided before the AI Act can come into force. The AI Act is intended to become effective two years after its entry into force, with the exception of certain specific provisions. Bans come into effect after just six months and the regulations on general purpose AI after twelve months.

At the time this annual report went to press, the Commission of Experts did not have the text of the agreement on the AI Act, but only information on the AI Act from the European Council, the European Parliament and the European Commission.[506] This forms the basis for the Commission of Experts' position on the AI Act.

The main elements of the planned AI Act can be summarized as follows:

- Field of application: The AI Act applies to public and private actors who develop or deploy AI systems. The obligations contained in the AI Act are not intended to apply to research, development and prototyping activities that precede the market launch. There are also to be isolated exceptions for developers of open-source models.
- Risk categories: The EU pursues a risk-based approach. A distinction is made between AI systems with unacceptable risk, high risk and minimal risk. AI systems with unacceptable risk are banned. These are AI systems that violate EU values, e. g. by enabling social scoring by authorities and businesses or recognizing emotions in the workplace. AI systems that pose a high risk to health, safety or fundamental rights must fulfil a number of requirements. These include assessing the impact on the protection of fundamental rights, data governance and transparency. The EU considers AI systems in law enforcement or in the operation and management of critical infrastructures to be high-risk systems, for example. AI systems that are associated with minimal risk, such as video games and spam filters, are not regulated. Special transparency requirements will be introduced for AI systems such as chatbots so that citizens are made aware when they interact with artificial intelligence.

Box B 4-16 Federal Government Strategies Related to AI

AI Strategy

In November 2018, the then Federal Cabinet adopted the 'Federal Government's National Artificial Intelligence Strategy' (AI Strategy).[507] One year later, the Federal Government published an interim report providing information on individual measures currently being implemented and those planned.[508] In December 2020, the Federal Cabinet decided to update the AI Strategy.[509] The Federal Government's measures associated with the AI Strategy are presented on the website www.ki-strategie-deutschland.de. As part of the AI Strategy, the AI competence centres have been further developed and new AI professorships have been created. Other key projects of the AI Strategy include the establishment of a data infrastructure and support for knowledge and technology transfer.

BMBF AI Action Plan

In November 2023, the BMBF published its own AI Action Plan, in which it announced that it would intensify its involvement in the AI Strategy with the aim of providing new impetus for the German AI ecosystem and its points of intersections with industry, education, science and research.[510] The AI Action Plan identifies eleven fields of action in the spheres of infrastructure, application and transfer as well as conditions for success and underpins them with targets and measures.[511]

Future Strategy Research and Innovation

The Future Strategy for Research and Innovation adopted by the Federal Cabinet in February 2023 contains a number of references to AI.[512] For example, transformation processes are to be actively structured with the help of AI and technological sovereignty is to be safeguarded.

Digital Strategy

Artificial intelligence is one of the strategic topics to be prioritized in the Federal Government's Digital Strategy, which was presented in August 2022 and updated in April 2023. It was announced that it would support skills development in the field of AI and further develop the AI Campus as a learning platform for artificial intelligence.[513] Artificial intelligence is also to be used for innovative services in the judiciary and to make environmental policy measures more efficient.

Data Strategy

The Federal Government adopted a new Data Strategy in August 2023. This aims to provide both more and better data than before and also explicitly refers to the importance of (high-quality) data for AI.[514]

- General purpose AI: General purpose AI systems (GPAI systems) and the foundation models on which they are based (GPAI models) must fulfil transparency requirements, which include the creation of technical documentation, compliance with EU copyright law and the dissemination of detailed summaries of training data. In the case of very powerful GPAI models that could present systemic risks, additional obligations must be accepted, for example regarding risk management, the monitoring of serious incidents and the performance of model evaluations.

- Governance: The market surveillance authorities responsible at national level will monitor the implementation of the regulations at national level. A new organization will be created within the European Commission to assume coordination at European level. This organization will also monitor the implementation and enforcement of the regulation of GPAI models. In doing so, it will be advised by a newly established committee of independent experts.

- Regulatory sandboxes: In a controlled environment, regulatory sandboxes are intended to enable innovative AI systems to be developed, tested and validated and the regulatory framework to be adapted to facilitate the roll-out of innovative AI systems.

The Commission of Experts welcomes the fact that the EU reached a provisional agreement on the AI Act in December 2023 and thus before the start of the European election campaign. The EU faced

the challenge of ensuring safety in the development and use of AI and safeguarding the European value system, while at the same time not restricting incentives for innovation too much.

The Commission of Experts believes that restricting the scope of the AI Act with regard to open-source development and research activities makes sense in principle. However, adjustments to these exceptions should be possible.

The Commission of Experts is generally in favour of the risk-based approach, according to which AI systems are assigned to different risk classes depending on their application.

In a departure from the otherwise risk-based approach, the EU regulates general purpose AI systems and models, which include large language models and multimodal models, not at the application level, but at the technology level. This includes transparency obligations for the developers of AI foundation models, which must now be specified in further negotiations. Care must be taken to ensure that the transparency obligations are kept within limits and that start-ups and SMEs in particular are not disadvantaged in comparison to larger companies.

According to the draft of the AI Act, foundation models are categorized as high-performance GPAI models solely based on the computing capacity used for training. However, this is of limited use as a sole indicator of the potential risk of foundation models. It is therefore important to consider further criteria when categorizing foundation models, as provided for in the provisional agreement on the AI Act.

When establishing new governance structures at EU level, there is a risk of cumbersome and bureaucratic structures being created that impede agile action and any adjustments that may become necessary over time.

It is to be welcomed that the AI Act provides for the instrument of regulatory sandboxes, as they facilitate innovation and at the same time enable regulatory learning.

B 4-8 Recommendations for Action

AI, which is developing very dynamically, is a key enabling technology. It is therefore important for Germany and Europe to boost their technological sovereignty in this area in order to maintain innovation and growth potential. It is essential not to lose touch with technological developments and to avoid becoming even more dependent on non-European providers. The aim should be to support the development of an efficient AI ecosystem. Since Germany and Europe hardly have any large IT companies, the stimuli from the scientific system, the contributions of SMEs and start-ups as well as open-source AI have a crucial role to play.

Reinforce Basic Research

The Federal Government should continue to firmly support basic AI research. This would give Germany the opportunity to successfully position itself in the international innovation competition for new technology variants and generations. The Commission of Experts welcomes the fact that the Federal Government is funding the Centres of Excellence for AI Research on a permanent basis.

— The Centres of Excellence for AI Research should be equipped in such a way that they can conduct cutting-edge research in the long term. This requires not only financial resources, but also an appropriate infrastructure, in particular computing centres and data.

— The goal formulated in the AI Action Plan of advancing research into efficient and resource-saving AI systems should be pursued as quickly as possible with corresponding targeted funding programmes. Germany and Europe should drive forward the development of AI models that are adapted to the given local conditions with as yet underdeveloped data and computing infrastructure such as Edge AI (cf. box B 4-1), federated learning (cf. box B 4-1) and AI applications on encrypted data.

Support Provision of Computing Capacities

There is a lack of computing capacity in Germany, which is a prerequisite for training and applying AI models.

— Powerful computing capacities must be created to accelerate the safe development of next-generation foundation models under controlled and transparent conditions and in line with European values, and to enable the development of open-source foundation models on a large scale.

— The commissioning of exascale-class supercomputers announced in the BMBF's AI Action Plan[515] must be driven forward quickly. SMEs and start-ups must be guaranteed access to these computers and services associated with their use must be provided.

Improve Data Basis for AI Applications

Given that extensive data sets are essential for the development of AI applications, it is essential to establish a powerful and competitive data infrastructure that can be used by science and industry, and in particular by SMEs and start-ups.

— The Federal Government as well as the Länder and local authorities should accelerate the provision of their own data.

— The Federal Government should provide a set of its own data and launch a call for proposals to support various teams, for example as part of 'challenges', that develop and test AI models and applications based on this data.

— The Federal Government should vigorously drive forward the measures it has initiated to improve the data infrastructure, for example in its AI Action Plan and Data Strategy.

— The Federal Government and actors such as Gaia-X, Catena-X and Manufacturing-X should swiftly develop data trustee models under the European Data Governance Act.

Expand AI Skills

The Commission of Experts emphasizes that an AI ecosystem is dependent on well-qualified professionals who conduct AI research, develop AI technologies and safely utilize AI applications.

— The modernization of the education system increasingly includes teaching skills in the utilization of AI. The Federal Government should work towards ensuring that appropriate programmes are provided in school, academic and vocational education.

— As established businesses clearly remain concerned and uncertain about the utilization of AI, they should be supported with advice and use cases, for instance via the SME competence centres (Kompetenzzentren Mittelstand).

Promote Open-Source AI

Open source harbours immense potential for strengthening Germany's and Europe's technological sovereignty. Open source is also seen as playing a significant role in the development of AI foundation models that guarantee transparency and are in line with European values. However, further initiatives are needed to promote the spread of open source and utilize the potential of open-source AI.

— Initiatives that reinforce the open-source developer community and are aimed at Germany's and Europe's technological sovereignty, such as the Sovereign Tech Fund financed by the BMWK, should be supported.

— The Federal Government should set up programmes to support the security architecture of open-source models via competitive tendering procedures.

— Research projects should be launched to better understand the development of open-source AI and its contribution to the AI ecosystem.

— The measures implemented to support open-source AI should be evaluated in order to promptly adapt funding measures.

Allow Regulatory Learning and Increase Legal Certainty

The European Parliament and the European Council have reached a provisional agreement on the AI Act.

— The AI Act should be adapted over time based on the knowledge and experience gained in regulatory practice in dialogue with actors from other economic and value areas. Without room for adaptability, regulation is unlikely to do justice to the dynamic development of this technology. If necessary, the allocation of applications to risk classes should be adjusted.

— In terms of governance, care must be taken to ensure that the bureaucratic burden for the stakeholders subject to the AI Act remains within reasonable limits, especially for start-ups and SME.

— The regulatory sandboxes provided for in the AI Act should be used as an instrument for regulatory learning as quickly as possible.

— The provisions of the AI Act should be dovetailed with existing regulations such as the Digital Markets Act, the GDPR and the Data Act to ensure consistent jurisdiction. In addition, competition law regulations should apply consistently in the AI sector.

— Since AI innovations in companies are hampered by legal uncertainty, especially in the fields of copyright law, the GDPR and the AI Act, the Federal Government should commission the creation of practical guidelines that facilitate the management of AI-relevant legal frameworks.