WISO DISKURS

14/2021

Heike Belitz, Martin Gornig, Claudia Kemfert, Ralf Löckener, Torsten Sundmacher

SETTING PRIORITIES, POOLING RESOURCES AND ACCELERATING TRANSFORMATION

New approaches in industrial and technology policy

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SUMMARY

Germany's industrial policies are facing new challenges posed by digitalisation and climate change. Industrial policies must now support structural change. Companies and federal states are having to be selective about the technology they specialise in because of both the rising costs in existing research activities, as well as the additional costs of new investments in game-changing technology. The German Federal Government should therefore sharpen the focus of its funding programmes towards key digital and climate-friendly future technologies.

At the same time, digitalisation requires new forms of cooperation between universities, companies and the government. It is often no longer tenable to separate application-oriented public research and private investment for commercial implementation. The government has to invest more in the implementation of product research. This will enable more permeable boundaries between pre-competitive research funding and investment aid.

The commitments made in climate agreements mean that industry needs to steer fundamental technological innovations right away from fossil fuels: oil, coal and gas. The need for innovation and investment is enormous, and the technological advances required often have a cross-sectoral and systemic character. These technological advances will only succeed if the government takes an active role. Key technologies require the development of appropriate infrastructures and alliances, the conversion of value chains, and not the least, massive support in the financing of investments.

Geopolitical tendencies towards protectionism and increasingly fierce competition in the triangle between Europe, the USA and China leave no room for business as usual. Accordingly, 2019 saw a reorientation in German industrial policy. The existing, somewhat passive industrial policy in Germany, is characterised by not giving preference to specific technologies ("openness to technology"). Also characteristic of existing German industrial policy is pre-competitive promotion. This policy has last been supplemented by specific-focus projects such as European IPCEIs (Important Project of Common European Interest) in the fields of micro-electronics and battery cell production, German and EU hydrogen strategies and Sprin-D, the federal German agency for disruptive innovation. These new approaches are positive. They should be evaluated, further developed and, if necessary, expanded in the future.

We are also currently dealing with a macro-economic investment crisis triggered by the global Corona pandemic. In Germany alone, investments in the second quarter of 2020 are almost 30 per cent down from the year before. Technology-oriented investment funds are a suitable instrument for supporting necessary industrial structural change since they link industrial and investment policies. With a clear focus on selected technologies, such targeted investment support programmes could generate new partnerships between companies and the German government. In turn, these partnerships can contribute to building technology leadership and realigning value chains. For this to work, the European level must also attain greater importance.

The state should share both the risks and successes with companies. This means that the concept of a strategic industrial policy should also include ways for the government to participate in the expected returns on its high-risk investments in new technologies, such as through dormant equity holdings.

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ISSUES AND CHALLENGES

In the wake of the Corona pandemic, Germany is currently experiencing the worst economic recession since World War II. This global slump is far more extensive than in the aftermath of the 2008 financial crisis (Stern et al. 2020). Since the industrial sector is at the core of the German economy, Germany will only get out of this slump if industry is put back on a track of growth (Belitz et al. 2020).

Here it is important to recognise that a strong and differentiated industry also guarantees prosperity in Germany in the medium term. German industry makes a significant contribution to securing the external value of the euro, which in turn secures purchasing power in Germany and the eurozone. In Germany, industry is responsible for well over 80 per cent of exports (Blazejczak et al. 2018). Industry also plays a significant role in the balanced distribution of prosperity. The high level of machinery used in this sector enables greater labour productivity. At the same time collective bargaining enjoys a high level of coverage. Both of these elements together contribute significantly to high wages, even in middle salary segments (Bosch/Weinkopf 2017; Gornig/Goebel 2018).

Industry has an important role to play in terms of technological progress. Industry is responsible for the majority of research and development expenditure in the German economy. Of all industrial sectors in Germany, the automotive industry accounts for about one third of all research and development (R&D) expenditure. One indicator of technological progress is the efficiency of production and, in particular, total factor productivity. Total factor productivity represents the growth that is realised above and beyond the pure increase in labour and capital input, primarily through innovation. According to empirical findings, like most other developed countries, Germany has recently suffered from pronounced weak productivity development (BMF 2017). Across the major sectors of the German economy, only industry still makes a noticeable contribution to total factor productivity growth. In view of demographic developments and the current increase in debt, Germany is dependent on these productivity gains. Without productivity gains, the prosperity of broad sections of the population is massively endangered.

Industry is therefore a fundamental factor in maintaining prosperity in Germany and Europe and is why it is so important to address the challenges this sector is facing. For example, for a number of years it has been quite apparent that although the industrial sector in Germany is characterised by high capital intensity, capital stock in German industry is becoming increasingly outdated. This can be partly explained by a pronounced weakness in investment (Belitz/Gornig 2019a). This does not only affect the traditional costs of buildings and machines. German industry has not invested enough in knowledge capital compared to other countries. Investments are even more essential in times of necessary climate protection and modernisation due to digitalisation.

The possibilities of digitalisation are fundamentally challenging existing business models. Industry value chains are being reconfigured. Data-related services are being established for the use of industrial products. There are completely new constellations of cooperation between producers and customers via platforms, as well as new interfaces between workers and the machines they use. Large digital companies have become new competitors entering the industrial sector creating entirely new markets.

This requires not only new ideas and business models on the part of industry, but also investments in machinery and the qualification of employees.

At the same time, to achieve climate targets, German industry must reduce emissions by about 24 per cent over the next ten years from current levels. This can only be achieved if production processes are geared towards climate neutrality as quickly as possible without losing short-term competitiveness. This, too, will only succeed with more investment in physical and knowledge capital.

Due to the current economic crisis, there is a threat that weak industrial investment will become entrenched, causing a prolonged economic crisis and a loss of competitiveness in German industries and the economy as a whole. The risks for investors are compounded by the Corona crisis. Uncertainties about both digital and conventional competitive future technologies as well as geopolitical conditions due to the America First strategy and Brexit have already dampened investment, and this is likely to decline even further with the virus-related threats in wider areas of industry.

In addition, the German innovation model tends to rely on incremental, small-step further developments, while the above-mentioned upcoming challenges tend to have the character of fundamental transformations and (must) often be accompanied by disruptive innovations.

Against this background, the question arises as to how the German government can contribute to mobilising urgently needed investments and innovations. In the following chapters, the potentials of a strategic industrial policy are highlighted in order to initiate the necessary processes. The starting point is a brief look at the different international approaches to industrial policy and a detailed description of current industrial policy initiatives. Links are then made to current challenges posed by digitalisation, decarbonisation and risks regarding globalisation in Germany. Building on this, approaches to a partnership-based and strategically oriented industrial policy are outlined.

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STRATEGIC INDUSTRIAL POLICY IN SCIENTIFIC DISCOURSE

In literature we find numerous attempts to catagorise the different forms of industrial policy (Meyer-Stamer 2009; Rehfeld/Dankbaar 2015). The most fundamental distinction is found between horizontal and vertical industrial policy (Rodrik 2014). The term horizontal policy refers particularly to general frameworks that are necessary for the development of industrial structures, such as the legal or education systems. Vertical policy, on the other hand, subsumes interventions in certain industrial sectors.

A brief look at industrial policy history in the Federal Republic of Germany will help illustrate these various policy approaches. After 1945, industrial policy in West Germany relied both on selective mechanisms such as the establishment of the VW Group under state guidance, as well as on creating favourable conditions such as the undervaluation of the Deutschmark as a general strategy to promote exports. We can observe this type of catch-up export-oriented industrialisation to some extent in China today, with its state-owned corporations and the government's stipulations that there be a certain amount of inland involvement in specific industrial activities.

The focus of industrial policy in Germany changed during the 1970s oil crisis when the need to restructure industry assumed a prominent role. In addition to the promotion of nuclear energy as an alternative to oil, it was hoped that the subsidisation of the coal and steel industries in particular would buy more time for restructuring in regions with declining industries. The US government's current tariff policies that aim to protect domestic industry are likely based on similar motives.

In the 1980s, industrial policy in established industrialised countries was increasingly oriented towards promoting the innovation system. In Germany, one such example is the establishment of an almost nationwide network of universities of applied sciences and Fraunhofer Society institutes. The emerging Southeast Asian nations, such as South Korea and Taiwan, essentially relied on technology policies, although these policies were more selectively aimed at high-tech industries (Cherif/Hasanov 2019).

From an economic perspective, technology policy intervention is necessitated by diverse types of market failure (Fritsch 2018). For example, since they are indivisible, research and production activities of a certain minimum size must often be achieved in order to make technological progress. Moreover, generating technological knowledge usually results in positive external effects. Thus, technological potential would not be fully exploited by market incentives alone. Accordingly, technology policy interventions by the government are essential where spill-over effects, network externalities or path dependencies exist (Mazzucato 2015).

Although it is undisputed that technology policy is necessary nowadays, there is disagreement concerning the form it should take (Belitz/Gornig 2019b). Two polarising views on this issue can be distinguished in a simplified way as follows:

- the liberal, non-interventionist view, which disputes the government's ability to identify future technologies and to select technologies worthy of subsidy, and which limits government activity to basic research and to defining competitive or infrastructural frameworks for new technologies (for example: SVR 2018);
- the formative, interventionist view, whereby setting priorities is considered indispensable, stipulates or even demands an active government role in selecting and promoting strategic future technologies (Atkinson 2015).

Following the financial and economic crisis of 2008/2009, there was a new wave of scientific discussion concerning the right approach to industrial policy (Aghion et al. 2011; Stiglitz et al. 2013). Arregui Coka et al. (2020) view the current transformation in industrial policy worldwide in the context of protectionism and innovation. They argue that industrial policy must strike a balance between protecting and promoting legitimate national self-interest on the one hand and fending off economically harmful protectionism and misguided state interventionism on the other. As this applies to Germany, Dohse et al. (2019) fear a new trend that leans towards autonomy, or "technology sovereignty", which would threaten the prosperity benefits of globalisation. Germany's restrained industrial policy has been and still is a great success. The authors oppose subsidising "national champions", which would deprive SMEs of scarce human resources and venture capital.

However, other academics insist that the task of industrial policy is to achieve strategic aims (e.g.: Aiginger/Rodrik 2020). In their view, industrial policy goes far beyond simply correcting market failures and is more a process of searching the unknown that not only benefits from a dialogue with experts, interest groups and citizens, but must also prevent appropriation by individual interest groups and populism. The core characteristic of strategic industrial policy is that support for structural change and growth in productivity cannot take place without considering the direction of technological transformation (Atkinson 2015). Thus, new industrial policy should guide technological transformation in industrialised countries in a more environmentally sustainable direction (Aiginger/Rodrik 2020). Nonetheless, it is conceivable and judicious to consider other technological focal points as well. A "new mission orientation" of industrial policy takes its position one step further (Mazzucato 2013). In this context, mission orientation means that comprehensive research programmes are initiated to solve major social problems. In the USA, research and innovation policy is traditionally mission oriented (Ergas 1987), as demonstrated by the lunar landing project. Germany's high-tech strategy has likewise been pursuing the paradigm of "mission orientation" since 2006 (Dachs et al. 2015). In this new mission orientation, Mazzucato (2013) additionally calls for German government innovation policy to be oriented towards social goals, thereby undertaking missions rather than promoting individual sectors, companies or technologies. The idea behind this new mission-oriented approach is that
it will create and shape markets while also rectifying market failures. The starting point is major social challenges, which are complex and systemic, interconnected and urgent. These issues require insight and knowledge from many different perspectives. By focusing on problems that require cross-sectoral solutions, a mission-oriented industrial strategy reinvents the vertical dimension of industrial policy. However, this also makes it more complex and more vulnerable to governmental and policy failures.

Key elements of mission-oriented policies are coordinated public investment and market-shaping policies to support experimentation and innovation (Kattel/Mazzucato 2018). The government should hereby stimulate demand and thus improve companies' expectations concerning future growth opportunities (Ryan-Collins et al. 2020)

A comprehensive policy concept with integrated mission-oriented innovation, investment and industrial policy requires an enormous coordination effort. By way of example, France learned some painful lessons in the 1960s with its planification model. But even today there are huge systemic demands on a comprehensive industrial and innovation policy oriented towards social missions in view of the complexity of innovation processes (Fagerberg/Hutschenreiter 2020; Lane 2020). This is where it is advantageous to have selective approaches of a strategic industrial policy that focus on the development of concrete technologies and their implementation in the value creation process. A current example of this is the establishment of battery cell production sites in Europe (Belitz/Gornig 2020).

At the same time, it should be remembered that strategic industrial policy cannot only focus on individual central missions (grand challenges). This applies to Germany in particular. The German innovation model tends to be oriented towards incremental, step-by-step developments, whereas the imminent challenges of major change often assume the character of fundamental transformations and often have to be accompanied by disruptive innovation. Consequently, a strategic industrial policy for Germany would also have to include mechanisms to support small-step measures (Löckener/Timmer 2020). In addition to elements of mission orientation, a strategic industrial policy should always include an approach that is open to all issues. This openness makes it possible to better exploit the knowledge of promising innovation potential available locally within companies. Mission-oriented and open-topic industrial policies are therefore complementary rather than mutually exclusive. Ultimately, the government should not only share risks with companies, it should also share the success of innovations that address societal issues (Belitz/ Gornig 2019b). Accordingly, a strategic industrial policy concept should also integrate procedures to provide the government with at least some returns on risky investments in new technologies to compensate for inevitable losses: Equity participation, conditions for reinvestment, price capping or by restricting the scope of patents (Mazzucato 2019).

4

STRATEGIC INDUSTRIAL AND TECHNOLOGY POLICY INITIATIVES

In this section we will focus on the current industrial policy measures that Germany, the EU, the USA, the UK and China are planning or have already recently taken by developing new technologies to solve key social problems, and how these have been implemented by in terms of investments. As a member of the EU, Germany must coordinate its industrial policy with the European Commission. The USA and China are important global competitors, and each of them are pursuing their own geopolitical and security interests. Following a long period of de-industrialisation, the United Kingdom is now pursuing a policy of building up its industrial capacity and is currently in the process of departing from the EU. In addition, the countries and regions under consideration have close economic ties with Germany through trade and the presence of multinational companies.

4.1 GERMANY

INDUSTRIAL STRATEGY 2030

Following an intensive series of discussions, in November 2019, the Federal Ministry for Economic Affairs and Energy (BMWi) published its Industrial Strategy 2030 with the subheading 'Guidelines for a German and European Industrial Policy' (BMWi 2019). The aim of this strategy is to join forces with commercial stakeholders and to contribute to regaining and securing economic and technological competence, competitiveness and industrial leadership on a national, European and global level in as many areas as possible.

The strategy comprises three pillars: In addition to improving the conditions for Germany as an industrial location described in Pillar 1, Pillar 2 aims at strengthening new technologies and mobilising private capital. Pillar 3 is concerned with the preservation of technological sovereignty.

PILLAR 2 OF THE INDUSTRIAL STRATEGY: STRENGTHENING NEW TECHNOLOGIES AND MOBILISING PRIVATE CAPITAL

The BMWi (the German Federal Ministry of Economic Affairs and Energy) has identified certain game-changer technologies that will "reshuffle the pack in global economic affairs". These currently include, according to the BMWi, artificial intelligence (AI), Industry 4.0, biotechnology and nanotechnology, lightweight construction and new materials. The German and European economies must aim at not only being the leading market in these technologies, but also lead providers.

Financing opportunities for game-changer technologies in particular are to be improved by means of a 10-billion-euro German Future Fund – though in principle the fund is open to all technologies. Among other things, this is supposed to encourage German institutional investors to provide venture capital. Here, both direct funding and a broad-ranging investment fund are envisaged.[1] The government's commitment within the framework of the Future Fund extends beyond the scope of existing venture capital funding and will facilitate major investment in future technologies. The model also offers expansion opportunities on the European level, for example through the involvement of the European Investment Bank (BMWi 2019a).

The High-Tech Strategy 2025 for Research and Innovation is also mentioned in the context of Pillar 2. The High-Tech Strategy, initiated in 2006, serves to improve innovation systems as a prerequisite for strengthening growth and competitiveness, as well as for overcoming social challenges. This strategy therefore has a significant overlap with industrial policy objectives (Dachs et al. 2015). The High-Tech Strategy follows the paradigm of the "new mission orientation". In contrast to the "classic mission orientation", which defines goals and

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1 On 1 April 2020, the Executive and Nominating Committee of the KfW Development Bank Board of Supervisory Directors commissioned KfW to develop a detailed realisation concept on the basis of key points developed by an inter-ministerial working group with KfW (Deutscher Bundestag 2020). The KfW was formed in 1948 as part of the Marshall Plan to assist the Federal German Government achieve its goals in development policy and international development cooperation.

technological developments with which they are to be achieved (for example, in the development of nuclear power and space travel), funding now has greater focus on helping solve social problems (climate change, demographic transformation, security), without defining technologies worthy of funding. The main share of funding in the High-Tech Strategy is still spent on issue-focussed funding for cooperative research projects, most of which are awarded in open competitions (Dachs et al. 2015). There has been repeated criticism of the technological focus of R&D funding: The Commission of Experts for Research and Innovation (EFI), for example, criticised the slow growth of funding for digitalisation (EFI 2017). The assessment criteria defining which topics and technologies are promoted are not always transparent or easy to understand. It should be noted that even the new mission-oriented policy, which is more open to technology and is orientated towards areas of need, is constantly required to take decisions on its direction and set technological priorities. From an economic perspective, the question as to how such priorities are set is undoubtedly the greatest challenge for a mission-oriented technology policy.

AGENCY FOR DISRUPTIVE INNOVATION (SPRIND)

Another component of Pillar 2 is the Federal Agency for Disruptive Innovation (SPRIN-D), established in 2019. Among the models for this agency are DARPA (Defense Advanced Research Projects Agency) at the US Department of Defense, and the US organisation ARPA-E (Advanced Research Projects Agency-Energy) (see also Section 3.3). The initial goal of SPRIN-D is to identify and promote research ideas that exhibit disruptive innovation potential. Even if this measure is initially open to different technologies, decisions on technological priorities have to be made. Therefore, idea competitions are held for cutting-edge projects that aim to realise R&D ideas that run for three to six years (BMBF 2018). The Federal Ministry of Education and Research (BMBF) is testing this new mechanism for funding disruptive innovations with three innovation competitions on the issues of energy-efficient AI systems, laboratory organ replacement and "world storage".

The agency for disruptive innovation is supposed to help technological innovations that are radically new and possess a high level of game-changer potential to break onto the market. Above all, in Germany, disruptive innovations should be exploited and more frequently introduced to the market.

TECHNOLOGIES AND AREAS OF APPLICATION IN INDUSTRIAL STRATEGY 2030

The Industrial Strategy 2030 outlines areas of application and identifies some technologies on which support measures are focused. Areas of application include future forms of mobility, low-CO_2 industrial production, the bio-economy and light-weighting.

In the field of digitalisation, the German government points out the enormous economic potential of AI and Industry 4.0. The German government's AI strategy announced in 2018, aims to support companies in fully exploiting this potential (see German government, n.d.). The AI strategy is also an element of the German government's digitalisation implementation strategy that was enacted in November 2018 (German government 2020a). This digitalisation strategy covers five fields of action, ranging from the promotion of digital competencies to the digitalisation of administration and the promotion of digital infrastructure. The area of activity covering innovation and digital transformation, which also aims to advance the cross-sectoral promotion of Industry 4.0, is of particular relevance in the commercial sector.

For "mobility of the future", battery cell production is a central issue in the industrial strategy. The BMWi will provide more than one billion euros for a number of innovative projects in this area, including the European IPCEIs (see also 3.2). The BMBF (the German Federal Ministry of Education and Research) and the BMWi will support the establishment of an innovation-based, comprehensive "battery value creation network" in Germany and Europe from 2020 onwards – from the production of raw materials to the manufacture of machinery and installations, battery cell production and recycling. A project closely linked to this is the BMBF's funding of 500 million euro for a "research factory" (BMWi 2019).

NATIONAL HYDROGEN STRATEGY (NWS)

The National Hydrogen Strategy (German government 2020b) that was announced in the Industrial Strategy 2030 and adopted in June 2020, is a broad-ranging and differentiated industrial policy strategy. The strategy allows the government to create a coherent framework for the future production, transport, use and re-utilisation of hydrogen and thus for associated innovations and investments.

Hydrogen plays a central role in the development and completion of the energy transition, because alternatives are required to replace the fossil fuels currently still in use. However, for hydrogen to become economically viable, the cost degression of hydrogen technologies must be improved. For this to be achieved, advances in production technology and economies of scale are essential. Here, particular focus has been put on areas that are already close to becoming economically viable or in areas identified as being difficult to decarbonise, such as the steel and chemical industries or in heavy-duty and long-haul transport. The German government's hydrogen strategy is aimed at laying the foundations for private investment in the economical and sustainable production, transport and use of hydrogen. A total of 38 government measures are supposed to spur the market readiness of hydrogen technology by 2023 and establish the basis for a functioning domestic market. These measures are the responsibility of the relevant ministries that are to provide the necessary financing within the frame-work of the applicable budget and financial plans (German government 2020b). Some examples of measures to promote R&D, innovation and investment in the field of hydrogen and fuel cell technology are as follows:

- The continuation of funding measures as part of the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP). Additional funding for hydrogen and fuel cell technology is available from the Energy and Climate Fund (EKF)[2] until 2023
- The EKF will provide up to 1.1 billion euros until 2023 for the development and promotion of facilities for the production of electro-fuels, especially bio-kerosene, and advanced biofuels.
- The development of a needs-based refuelling infrastructure is being promoted to supply vehicles also in heavy road freight transport, local public transport and local rail passenger transport. Until 2023, the EKF can dispense up to 3.4 billion euros for this purpose across all alternative technologies to subsidise the construction of refuelling and charging infrastructure.
- Support for the development of a competitive supplier industry for fuel cell systems (fuel cells and components for fuel cell systems) including the creation of an industrial base for large-scale fuel cell stack production for vehicle applications.
- Exploring the creation of a technology and innovation centre for hydrogen technologies for fuel-cell vehicles and supporting the establishment of a German fuel cell system provider for logistics and intralogistics.

By 2030, the BMWi aims to allocate 7 billion euros for the market readiness of hydrogen technologies in Germany and an additional 2 billion euros for international partnerships (Altmeier 2020).

GOVERNANCE AND MONITORING OF THE NWS

To counteract uncertainty in long-term projects, the NWS will be updated in a three-year cycle and adapted if necessary: a monitoring procedure will assess market developments and make the required adjustments. A hydrogen council of recognised experts will also be founded in addition to a committee of state secretaries, a federal-state platform and a hydrogen coordination centre. These bodies will collaborate closely to further develop the action plan. From its inception, the NWS has embodied the notion of continuous development (BMWi 2020b).

PILLAR 3 OF THE INDUSTRIAL STRATEGY: SAFEGUARDING TECHNOLOGICAL SOVEREIGNTY

The German government's industrial strategy identifies an increased need for scrutiny in cases where non-EU investors seek to take over critical infrastructure or defence-related companies. This also applies to cases where the freedom of international capital movement in Germany is used by companies from non-EU states to pursue strategies that could threaten Germany or Europe's technological sovereignty. This applies in particular to the area of sensitive technologies, for example dual-use technologies. Loss of expertise must be avoided, and self-determination preserved in key technological areas. In individual cases, the government can invest in companies for a limited period via the KfW development bank in the case of sensitive or security-relevant technologies ("called the national recourse option"). To this end, structures are to be created to facilitate fast and efficient decision-making in the relevant areas.

4.2 EUROPEAN COMMISSION

In March 2020, the European Commission published a new industrial strategy for Europe. This marks the beginning of a new stage of industrial policy, but is still largely only a declaration of intent. It remains to be seen how the ambitious strategy will be implemented.

This industrial strategy sees three drivers for the transformation of industry:

- ecological transformation
- digital transformation
- global competitiveness

The transformations strived for in this industrial strategy will require new technologies and thus corresponding investments and innovations (EU Commission 2020a). The strategy also acknowledges that Europe will have to accept occasional setbacks when increasing investment in disruptive and pioneering research and innovation.

An important aspect of the European industrial strategy is the modernisation and decarbonisation of energy-intensive industries. For example, the European Commission will support breakthrough technologies that lead to CO_2-free steel production. The innovation fund from the EU Emissions Trading System is supposed to support more large-scale innovative projects to promote clean products in all energy-intensive sectors.

The European Commission will also systematically analyse the risks and needs of various industrial ecosystems in addition to horizontal measures designed for specific technologies. To carry out this analysis, the Commission will work closely with an industry panel established in September 2020. The panel will be composed of commercial representatives, including small and medium-sized enterprises (SMEs), large companies, social partners and academics, as well representatives from member states and EU institutions. The Commission's annual Industry Days will continue to bring together all relevant stakeholders (European Commission 2020b).

A European Innovation Council (EIC) is scheduled to begin operating in 2021. The Council will identify next-generation technologies, accelerate their commercial exploitation and ensure that they contribute to the rapid expansion of start-up companies (European Commission 2020b). The EIC brings together the most important EU instruments under one roof. The European Commission's goal here is to allow innovations to reach the market more quickly, thereby creating growth and employment (see also BMWi 2020c).

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2 Funding from the Energy and Climate Fund (EKF) established in 2011 can be used to implement the energy transition. The EKF is based on the Act on the Establishment of an 'Energy and Climate Fund'. The EKF is a so-called "special fund" and is financed, in addition to federal subsidies, from the proceeds of European emissions trading. In 2019, 4.5 billion euros were made available for programme expenditures (BMWi 2020a).

NEW PATHS TO MOBILISING PRIVATE INVESTMENT

At a time when governmental budgets are under pressure, the European Commission is trying to open up new ways to mobilise private investment. InvestEU and the European Green Deal Investment Plan have been launched for this purpose. The InvestEU programme is comprised of a fund, an advisory platform and a website interface bearing the same name. Running from 2021 to 2027, InvestEU builds on the success of the European Fund for Strategic Investments (EFSI).[3] In view of current challenges, the European Commission expanded its original InvestEU proposal in spring 2020 in order to better respond to the current economic crisis. The new proposal will double the funding to Sustainable Infrastructure policy areas to 20 billion euros. Moreover, 31 billion euros is earmarked for a new Strategic European Investments policy area to promote and secure strategic autonomy in key sectors.

The InvestEU fund will back investment projects supported by the European Investment Bank (EIB Group) and other financial partners by means of an EU budget guarantee totalling 75 billion euros, increasing their risk-bearing capacity. The new Strategic European Investments policy area focuses on building stronger European value chains and supporting critical infrastructure and technology activities (European Commission 2020d).

This industrial strategy considers public-private partnerships an important driving force behind the development of these technologies, as illustrated successfully within the framework of industrial alliances such as the European Battery Alliance created in 2017 and the microelectronics alliance between European member states and industry that have resulted in IPCEIs

IMPORTANT PROJECTS OF COMMON EUROPEAN INTEREST – IPCEI

Private investment and public funds must be mobilised across borders along important value chains to help protect against market failure in the large-scale introduction of innovative technologies. To facilitate this process, the European Commission has defined the Important Projects of Common European Interest (IPCEI) already mentioned (EU Commission 2020a). As part of this new instrument, the EU Commission already approved 3.2 billion euro for a pan-European IPCEI initiative on battery cell production in December 2019. The aim is to support the establishment of a strategic battery value chain, ranging from the extraction of raw materials to the development of innovative battery cells and systems and the recycling of materials for which BMW, BASF and Varta are involved from Germany.

A new European alliance for green hydrogen is also to be established by building on the successful blueprint of existing industrial alliances. Here, alliances in the areas of low-carbon industry, industrial clouds[4] and platforms, and raw materials should then follow in due course (EU Commission 2020a).

With these innovation projects, the EU Commission and the participating member states are to make directional decisions and set technological priorities. This entails the same high technological and financial risks that private companies normally face. It is important that the evaluation criteria for the selection of these projects is as transparent and comprehensible as possible. To be eligible for IPCEI funding, a project must (1) contribute to the EU's strategic goals, (2) involve several member states (at least two states), (3) involve private financing by the beneficiaries, (4) have positive spill-over effects across the EU limiting possible distortions of competition, and (5) be highly ambitious in terms of research and innovation.

IPCEI also seek to address state aid and competition concerns. This way, the results of the battery cell funding projects will also be available to the European scientific community and passed on to companies that are not directly involved in the projects. The results are to be presented at an annual public conference. Supervision of the projects will be covered by a steering committee consisting of representatives of the EU Commission, the participating member states and the companies participating in the project. Furthermore, a considerable part of the additional profits of the participating companies should be returned to the taxpayers through a claw-back mechanism. The instrument is to be further optimised on the basis of experience to date and the IPCEI communication adapted accordingly (BMWi 2019a).

STRENGTHENING EUROPE'S INDUSTRIAL AND STRATEGIC AUTONOMY

In order to strengthen Europe's strategic autonomy, the EU Commission believes that dependencies on other countries in areas such as critical raw materials and technologies, food, infrastructure, security and other strategic sectors must be reduced.

Risks are associated with foreign investment, and Europe wants to be more strategic in this area. From October 2020, the fully applicable FDI (Foreign Direct Investment) screening framework will ensure that Europe's security and public order interests are protected. For example, Europe's security and technological sovereignty depends on strategic digital infrastructures, among other things. The Commission has therefore taken action in the areas of 5G and cyber-security and will develop a critical infrastructure for quantum communications.

In addition, the European Defence Fund will help build an integrated industrial defence base across the EU. It will invest along the entire value chain of the European defence industry, facilitate cross-border cooperation and support open and dynamic supply chains. In addition, the fund will promote disruptive technologies, enabling companies to take on more risk.

CRITICISM FROM GERMANY

The Federation of German Industries (BDI) has criticised the new European strategy saying that it has the characteristics of a paternalistic industrial policy; it wants to set "goals, pace and direction for the coming years", but only rudimentarily emphasises the role of competition and the market.

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3 As of July 2020, 515 billion euros of additional investments had been released by the EFSI (see European Commission 2020c).

4 The IPCEI instrument is also to be used for the European GAIA-X cloud project.

According to the BDI, the Commission largely narrows the multiple challenges to ecological and digital transformation. Notwithstanding the current Covid-19 crisis, the extent of which was not yet foreseeable at the time the strategy was published, other major trends such as the changing framework conditions of globalisation, demographic transformation or increasing security risks also pose challenges for the economy and society and must remain on the industrial policy radar (BDI 2020).

The German Trade Union Confederation (DGB) has criticised a lack of concrete statements on financing. They say it is not enough to hope for private participation (for example through PPPs) or to divert resources from the structural funds to industrial policy projects. Instead, the budget must be substantially increased. If funds from already existing funds are only reallocated, this will not result in the necessary additional impulse in total. DGB calls for the permanent relaxation of debt rules so that member states can pursue active industrial policies (DGB 2020a).

4.3 USA

The U.S. does not explicitly pursue any specific industrial strategy, but it has long used instruments to promote new technologies and their introduction into local production and the market. In addition, the USA is considered a model country for mission-oriented research and technology policy (Ergas 1987). In this respect, the USA is a paradox. While publicly adopting a market fundamentalist stance, policy makers are actively undertaking industrial policy measures, for example to promote basic technological innovations ("general purpose technologies") (Wade 2014). According to Robert Atkinson, the widely held view that U.S. success is guaranteed by means of free markets, property rights, and the entrepreneurial spirit is naïve and lacks a historical basis. Conversely, government support for R&D, tax incentives, defence technology development initiatives and others have long played a key role in U.S. technology policy (Atkinson 2020). In the absence of a formal industrial policy, the U.S. supports industry indirectly and with minimal coordination. There is, however, a de facto industrial policy whose contours and mechanisms are rarely questioned (Clark/Doussard 2019).

Mazzucato (2013) studied the direct contribution of government programmes in the U.S. to innovation, which is generally considered to be the result of private entrepreneurial investment. For example, the study shows that many components of Apple's iPhone, including its touchscreen technology, were originally developed thanks to government subsidies and, in particular, U.S. Department of Defense programmes. The same applies to the key innovations of the internet and computers. Singer describes 22 cases of important technological innovations that have their origins in government-funded R&D projects in the U.S., such as the Google search engine, the Human Genome Project, MRI and lactose-free milk (Singer 2014).

ADVANCED RESEARCH PROJECTS AGENCY (ARPA)

The most important institutions for the development and commercialisation of research results include the Defense Advanced Research Projects Agency (DARPA) of the Department of Defense (founded in 1958), the Advanced Research Projects Agency-Energy (ARPA-E) of the Department of Energy (founded in 2009) and the Intelligence Advanced Research Projects Agency (IARPA of the Office of the Director of National Intelligence; founded in 2007), as well as the Manufacturing USA Network.

These three ARPA agencies have ambitious models for organising innovation and are public intermediaries between academia and industry, pursuing mission-driven risk- and promise-based research for technological breakthroughs. They also actively support the further development and introduction of new technologies in their mission fields (Bonvillian 2018).

Important characteristics of these agencies are:

- demanding technical goals
- organisational independence
- unbureaucratic processes
- qualified, experienced managers and a lean management
- temporary R&D teams
- technically demanding and financially strong customers
- continuous management, no post-hoc evaluation
- credible accountability procedures
- effective policy design (Bonvillian et al. 2019).

DARPA had a budget of 3.5 billion U.S. dollars in 2020 and distributed the funds to small projects by engineers and researchers, as well as to start-ups, established companies and industrial consortia. The projects address many technological possibilities for developing new solutions to national security problems. The fact that individual efforts fail is accepted as a natural consequence of high risks, because "the whole portfolio delivers". The DARPA model has led to great discoveries and technological progress since its inception, such as the internet, GPS and voice recognition systems (DARPA 2020).

NATIONAL NETWORK OF MANUFACTURING INNOVATION

The National Network of Manufacturing Innovation is the closest embodiment of a formal industrial policy measure. The initiative started in 2012 and was realised with the Revitalise American Manufacturing and Innovation Act of 2014 (RAMI Act 2014). This links federal investments and regional industrial complexes with the goal of creating jobs (Clark/Doussard 2019). So far, 14 institutes have been established as public-private partnerships.

The core idea of the network is that each institute acts as the centre of a local cluster of companies around a particular technology. However, each institute should also have the means to collaborate with partners outside the cluster and abroad (Block et al. 2020).

In 2017, these institutes had 1,291 members, of which 844 were industrial companies, 297 were educational and academic research institutes, and 150 were other entities such as federal, state or local governments, government research labs and non-profit organisations. 65 per cent of the participating companies had less than 500 employees. The total expenditure of the institutes was 298 million U.S. dollars in 2017 (National Academies of Sciences 2019).

Over the last few months in the USA, voices have been increasingly calling for an explicit industrial strategy, especially against the backdrop of China's ambitious industrial strategy and growing technological strength, as well as to preserve national security. For example, Atkinson (2020) calls on the U.S. Congress to provide greater support for R&D in key technologies, offer tax incentives for the development of advanced manufacturing, co-finance the expansion of domestic production of new technologies and introduce competitive screening for regulation. All actions should be coordinated with companies from countries that the U.S. is allied with. Without its own strategy to strengthen advanced industries, America will, in his view, experience a steady erosion of its competitive position, similar to the UK in the 1960s and 70s, while facing a rise in populism at the same time (Atkinson 2020).

GOVERNMENT LOAN GUARANTEES – THE SOLYNDRA AND TESLA CASES

Under a U.S. Department of Energy government loan programme to promote green technologies that the Obama administration launched in 2009 (American Reinvestment and Recovery Act), several companies in the USA were supported with large government loans. Among others, Solyndra, a solar cell manufacturer founded in 2005, received a loan guarantee of 535 million U.S. dollars to complement private investment funds of 450 million U.S. dollars. The electric car manufacturer Tesla Motors was also supported in 2009 with a loan guarantee of 465 million U.S. dollars. While Solyndra went bankrupt in 2011, Tesla Motors repaid its loan ahead of schedule in 2013 after going public. This triggered a debate in the U.S. about the justification of risky government support for investment in new technologies and how it should be done (Rodrik 2014). In the case of Solyndra, criticism was aimed at government's "mistake" of investing an unsuccessful company, putting the burden on the taxpayers. Here, Rodrik argues that there is no reason to expect that the government should recover every loan from a programme that co-finances high-risk projects with environmental and technological externalities. However, such funding programmes should be safeguarded against political manipulation and lobbying, and the government should be able to withdraw the funding if there are signs of failure (Rodrik 2014). In the case of Tesla, there was criticism that the state did not record losses because the loan was repaid ahead of schedule. At the same time, this was only possible because of the company's rapidly rising stock market value. The government did not profit from this increase in value, but private investors did, although the state had borne a considerable part of the risk. Therefore, the government should consider providing its support in the form of equity participation in the future (Woolley 2013).

4.4 UNITED KINGDOM

In 2012, the UK government declared a new "sectoral approach" to industrial strategy (Department for Business 2012). The reasoning for this new approach was that it was recognised that long-term, high-risk investments in the national interest could not be fully financed privately and thus required public support. Strategies have been developed, for example, for the life sciences, energy (nuclear, oil and gas) and aerospace sectors. Even at that time, there was a clear trend away from an emphasis on a "horizontal" and regional focus towards a more strategic national approach in partnership with industry towards key sectors (O'Sullivan et al. 2013).

WHITE PAPER 2017

The importance of the "sectoral approach" remained significnat in the White Paper on the Industrial Strategy of the United Kingdom (GOV.UK 2017). So-called sector deals were then concluded, i.e. partnerships between government and industry sectors with concrete measures to solve the problems on a sector-specific level. The sector deals should ultimately lead to increased productivity, employment, innovation and qualifications. Such sector deals already exist, for example, in the aerospace sector, in healthcare, the construction industry, in artificial intelligence, the vehicle manufacturing sector, the offshore wind energy sector and others.

However, the Industrial Strategy White Paper also explicitly ascribes a responsibility to government that goes beyond promoting competition and framework conditions for industry (GOV.UK 2017). After consultations with leading scholars and engineers, four major challenges for society were identified: Artificial Intelligence and Big Data, clean growth, the future of mobility and the ageing of society.

To meet these challenges, substantial public and private investments are to be mobilised. The most important instrument for this is the Industrial Strategy Challenge Fund (ISCF).

The ISCF aims to combine UK research and business investment to develop new technologies that transform existing industries or create new ones. ISCF funds will be invested in world-leading research and in innovative companies to address today's major industrial and societal challenges. Investments here are focused on areas of strategic importance to the UK, including the development and manufacture of electric vehicle batteries and the efficient use of renewable energy, as well as artificial intelligence and robotic systems for extreme environments, or satellites and technologies for the manufacture of medicines. A total of £4.7 billion has been earmarked for the fund over four years (UK Research and Innovation 2020). The funds are awarded to projects in competitions on individual topics, ranging from research to the production of prototypes. As a rule, the companies involved in the projects invest private funds in roughly the same amount.

In a first assessment of the progress achieved in the implementation of the Industrial Strategy 2020, the independent Industrial Strategy Council also addressed the ISCF (Industrial Strategy Council 2020). The £2.5 billion provided in the first three instances from the Fund is an important contribution to the government's planned increase in R&D expenditure in the Council's view. However, the funds could be better used to stimulate additional private R&D investment. The Fund's focus on the later phases of the innovation process can help create incentives for industry co-investment and maintain the transfer of ideas from research to commercial use. This Fund is also the only one that explicitly addresses the 'grand challenges' of society. In view of the size of the tasks and the little noticeable progress so far, the evaluators believe that the Fund should be increased.

The UCL Commission[5] criticises that the ISCF is still too supportive of specific technologies and sectors because programmes for their promotion are lacking in the UK so far. In their view, the ISCF should focus less on individual technologies and more on mission goals and problem solving for grand challenges. It should therefore also be complemented by parallel funding to finance new technologies, so that the pursuit of missions and grand challenges does not crowd out funding for technologies that are not yet linked to missions (UCL Commission 2019).

Innovation requires patient long-term and mission-oriented financing. Internationally, the UK could learn from public venture capital funds for start-ups such as Yozma in Israel and public banks such as the Kreditanstalt für Wiederaufbau (KfW) in Germany or the European Investment Bank. A capital increase and a reform of the remit of the British Business Bank may be necessary (UCL Commission 2019).

From the perspective of the independent Industrial Strategy Council, there is little evidence so far of good industrial strategy coordination within government. However, improved policy coordination is potentially one of the most important benefits of an industrial strategy. In addition, the awareness and understanding of the industrial strategy should be improved among all social stakeholders in order to increase its effectiveness (Industrial Strategy Council 2020).

4.5 CHINA

In 2015, the Chinese government presented its ambitious Made in China 2025 (MIC) strategy in 2015. This industrial policy programme shows China's global ambitions as an industrial superpower. This industrial policy strategy defines the goal of achieving a sustainable development by the country's 100th year. China's goal is to become a major industrial power leading the development of the global industrial sector by 2049, the 50th anniversary of the founding of the modern Chinese state. The MIC 2025 identifies ten key industries in which China aims to become the global technology and innovation leader by 2049 (Arregui Coka et al. 2020; Zenglein/Holzmann 2020).

The MIC 2025 envisages the transfer of the previously nationally oriented strategy of vertical technology support to the global scale (Heinrichs et al. 2020). China's approach essentially corresponds to the East Asian development model with the rapid economic growth of the four 'tiger economies' of South Korea, Taiwan, Hong Kong and Singapore since the 1980s (Zenglein/Holzmann 2018; Cherif/ Hasanov 2019).

In the view of the EU Commission, China's proactive and state-led industrial and economic policies aim to develop domestic champions and help them become global leaders in strategic high-tech sectors (EU Commission 2019a). This also involves the crowding out of foreign competition. In summer 2018, the Chinese government reacted to international criticism of "Made in China 2025" by removing the term from official usage as far as possible. Beijing has not retreated from its major goal of making China a leading global industrial nation with the help of accelerated industrial policy (Zenglein/ Holzmann 2020).

Chinese industrial policy uses extensive state funds and subsidies that can be targeted at specific areas (Wübbeke et al. 2016). For example, national lead funds are available, such as the 'Big Fund' for the semiconductor industry with a volume of 44 to 57 billion euros, as well as hundreds of investment funds by local governments (Zenglein/Holzmann 2020).

In 2017, China announced its intention to become the world leader in artificial intelligence by 2030. In July 2018, the Chinese state-owned corporation CMG decided to establish a technology fund (the China New Era Technology Fund) with 15 billion U.S. dollars for this purpose. The fund is set to invest in technology companies in China, but also on a global scale (BMWi 2019b).

Some observers expect the MIC 2025 strategy to create a small avant-garde of Chinese manufacturers with high productivity. These frontrunners are likely to dominate their sectors in the Chinese market and become strong competitors in international markets. At the same time, the effectiveness of the strategy is limited by the mismatch between political priorities and industry needs, the fixation on quantitative goals, inefficient resource allocation and campaign-like overspending by local governments. The lack of bottom-up initiatives and investment is also a pronounced weakness of the MIC 2025 (Wübbeke et al. 2016).

Zenglein/Holzmann (2020) see the first successes of China's industrial policy in the area of vehicles with alternative drive technologies, the new telecommunications standard 5G, or in space travel, among others. Downsides, such as industrial overcapacity, would be accepted in order to establish value chains in the country and to quickly set themselves apart from international competition.

To access foreign technologies and expertise, China is pursuing multiple approaches that include cooperation projects, targeted foreign investments and company acquisitions. The lack of legal pursuit of intellectual property theft and employee poaching are considered to be part of the strategic repertoire of Chinese stakeholders. In strategically important areas of new technologies, regulations in China are initially kept deliberately loose to allow for innovative entrepreneurship and scientific breakthroughs. Foreign companies and research institutions are also attracted by this and want to benefit from great potential of the highly dynamic Chinese market.

5 The UCL Mission Oriented Innovation and Industrial Strategy (MOIIS) Commission, led by Mazzucato and Willetts, was established in March 2018 to advise the UK government on how to identify the need for innovation and technology to solve grand challenges in the implementation of the Industrial Strategy.

The relocation of entire innovation and value chains to China has already begun – even in areas that are highly sensitive in terms of competition and security policy (Zenglein/ Holzmann 2020).

The risks associated with investments in China for foreign investors are illustrated by the example of leading South Korean manufacturers of batteries for electric vehicles, who have been practically excluded from supplying their batteries to China. Korean companies built their production facilities in China after the Chinese government decided to subsidise batteries. Once the factory was ready for full operation, the Chinese government revised the regulations. In a bizarre twist, Korean companies with cutting-edge battery technology were unable to supply their batteries to Chinese customers. Meanwhile, local Chinese companies had a de facto monopoly to supply batteries for all electric vehicles manufactured in China. In this case, what China proclaims as legitimate industrial policy is in fact blatant discrimination against foreign companies (Choi 2020).

4.6 AGGREGATION: ELEMENTS AND CHARACTERISTICS OF INDUSTRIAL POLICY INITIATIVES

In developed nations, there was a long period in which the only accepted framework to improve conditions for industry were horizontal policy approaches. At the same time, there was a rejection of the idea of governments supporting individual sectors and companies that are either no longer or not yet competitive. The liberal economic mainstream sees the role of governments only in creating a dynamic competitive environment for companies and eliminating market imperfections. More recently, measures of vertical industrial policy, and especially technology policy, have increasingly come into focus as a reaction to the climate crisis, the challenges of digitalisation, and shifts in power in global competition. The aim is to modernise industries and entire value chains or create new ones, for which there are now explicit industrial strategies in all the countries considered, as well as the EU. Before the recent introduction of measures from the Biden administration, the exception here was the USA, which nevertheless also pursued vertical industrial policy measures. Focus is usually placed on radical innovations, new general-purpose or game- changer technologies whose development and introduction cannot be financed by individual private companies.

Recent industrial policies have provided substantial government investment to companies, research institutions and often consortia of both, not only to develop new technologies but also to help them break through to the market. Also being pursued are new ways of government and companies jointly financing the development of new value chains for innovations that are experimental in nature and not without controversy. These include the EU’s IPCEI projects, the U.S. ARPA agency-inspired SprinD agency in Germany and the Industrial Strategy Challenge Fund (ISCF) in the UK.

In mostly competitively organised procedures, project proposals are selected with technological solution concepts that are increasingly directly related to major societal challenges (mission orientation). In this selection process, other project ideas are inevitably discarded. Investment funds in R&D and in physical capital are concentrated on individual future technologies and fixed over longer periods. This is associated with great opportunities for technological leadership in international competition, but also risks of failure. The success of such investment promotion is likely to depend on the concrete design of project selection, the cooperation between the state and the companies in project implementation, their supervision and control, and the participation of both sides in risk and profit. However, given the short time span since the announcement of the new support measures, their impact on the competitiveness of companies and on international competition can hardly be comprehensively assessed at this stage.

The traditional scepticism of economists towards industrial policy is based, in the view of (Rodrik 2014), on the difficulties of achieving targeted and effective interventions in practice. Based on his analysis of the institutional design of green industrial policy in selected countries (USA, Germany, China and Japan), he proposes three principles for a new industrial policy:

1. Embedding: An appropriate industrial policy framework must create space for learning from state institutions. This in turn requires a considerable amount of interaction and communication between the public and private sectors.
2. Discipline: This requires clear measurable goals, close monitoring, proper evaluation, well-designed rules and professionalism. Guidelines and programmes need to be continuously adapted and “losers” should be excluded from funding if warranted by circumstances.
3. Accountability: Public bodies must explain what they do and how they do it. They must report on their failures as openly and transparently as they report on their successes. Accountability not only ensures the probity of public agencies, but also helps legitimise their activities.

5

CURRENT CHALLENGES FOR GERMANY AS AN INDUSTRIAL LOCATION

5.1 DIGITALISATION AND NEW FUTURE TECHNOLOGIES

In Germany there is currently a lot of discussion about the digitalisation of the economy. The term digitalisation covers many very different aspects of economic structural change (OECD 2019; Barefoot et al. 2018). At its core, this is about the use of data and algorithms as a production factor or as a component of processes and products. Characteristics of digitalisation are the virtualisation and networking of individual processes and products, data sharing, as well as organisation and control by means of digital platforms.

However, the use of digital technologies does not directly lead to a digital penetration of the economy (Lichtblau et al. 2018). It is possible to distinguish different levels of maturity of digitalisation. At the lower levels, this concerns the use of digital technologies in isolation or at least integrating them into analogue systems.

Further along the scale, digital technology is used for analysis, evaluation, prediction and ultimately decision-making.

If we look at more recent developments, we see digitalisation in many different forms (Capgemini 2019; McKinsey 2016). Software and data management systems are revolutionising the processing of information (smart operations). Apps and analysis systems create data-based and networked service offerings (smart services). Companies and consumers use virtual platforms and offers on the infrastructural basis of the internet that are mostly associated with high fixed costs and low marginal costs, as reproduction and networking do not entail extra costs. (Demary/Rusche 2018; Pascale 2018; Autor et al. 2017). Such network effects quickly gave rise to new giants of digitalisation such as Google, Amazon, Facebook or Alibaba.

Outside the internet economy, there are many sectors in Germany in which digital penetration, or the maturity of digitalisation is still relatively weak (Weber et al. 2018). Ultimately, digitalisation will fundamentally revolutionise physical production (Hüther 2016). New integrated production processes (smart integration) are being created because areas such as energy, transport and factory machinery are being networked in cyber-physical systems. In this way, components and end devices become producers and users of data infrastructures (smart products).

In Germany, with its traditionally strong industrial orientation the digital transformation in the physical world was titled ‘the fourth industrial revolution’ and ‘Industry 4.0’ in the early 2010s (Boston Consulting 2016; Lichtblau et al. 2015). The fact that developments in digital technologies are given the same significance as the development of the steam engine, electrification and computers should give an indication of just how fundamental these the changes will be for industry.

At the same time, the term ‘fourth industrial revolution’ also makes it clear that many parameters of the economic changes brought about by digitalisation are still largely open. Thus, in retrospect, typical modes of production and work organisations can also be assigned to the various industrial development phases. These are likely to have influenced economic effects more than purely technological innovation. The first industrial revolution was not only marked by the steam engine, but also by the mechanisation of manual production processes. In addition to technological innovations, the second phase is primarily characterised by standardisation of production processes and mass production advantages. The third phase is characterised by computer-supported automation processes and modular work flows with correspondingly differentiated product ranges.

The most decisive characteristic of the digital revolution is networking. What remains to be seen is just how this will affect the organisation of work. Some observers see great potential in digitalisation for increasing product diversity while unit costs continue to fall (Krenz et al. 2018; Koren 2010). This is where more traditional economies of scale do not apply. With the kind of additive manufacturing technologies such as 3D printing, industrial production can entail personalised one-off production. Consumers are no longer at the end of the production process but are becoming a part of it. Other observers see increasingly deserted factory floors where robots independently undertake production processes while controlling and repairing themselves (Frey/Osborne 2017). Still others expect human-machine combinations to prevail in the production process (McKinsey 2017).

Exactly which forms of organisation will prevail in different cases depends on a number of different factors. The economic realisation of the fourth industrial revolution will be determined by a combination of factors including technological breakthroughs coupled with customer preferences and their willingness to pay for them, but also regulations and specific institutional arrangements (Monopolies Commission 2015; Institut der deutschen Wirtschaft Köln/ IW-Consult 2016). Who has what rights and securities to what kind of data and algorithms, or who can use virtual platforms and how, will essentially determine which organisational and business models will prevail.

While it is clear that digitalisation will significantly change the industrial landscape, it is often unforeseeable exactly what forms and paths of development this will take. Accordingly, we are currently facing enormous uncertainties. These come with the paradox that digitalisation promises previously unimagined efficiency and growth potential, while at the same time, when observed through a long-term comparison, it becomes clear that production growth rates and productivity are steadily declining (Van Ark 2016). This paradox is primarily caused by the uncertainties themselves. Investments in analogue technologies are not made because there is uncertainty about whether these will be enduring solutions or quickly superseded by emerging technology, while investments in digital technologies are often not made because it is unclear which paths will prove to be the most promising. In turn, this low level of investment in both physical and knowledge capital reduces productivity gains. This constellation is also familiar from the observation of long waves of economic development; so-called Kondratieff cycles (Mensch 1975; Gornig 2000)

What consequences do the changing demands of digitalisation now have for industrial policy?

In view of the high level of uncertainty, educating people about the potential, opportunities and dangers of digitalisation is an important task for policy makers. The German Federal Ministry of Economic Affairs and Energy (BMWi) has launched initiatives and campaigns accordingly. For example, an Industry 4.0 mission statement (BMWi 2020d) was developed and an Industry 4.0 platform (BMWi 2020e) was set up specifically to demonstrate exemplary applications. Several funding programmes are aimed at supporting digitalisation processes in small and medium-sized companies (BMWi 2020f; BMWi 2020g). These also have numerous practical examples and accompany concrete digitalisation strategies. An important communicator for digital transformation is the Future of Industry Alliance. Comprised of partners from trade unions, business and employers' associations, the Association of German Chambers of Industry and Commerce and the Federal Ministry of Economic Affairs and Energy have been working together in this Alliance since 2015 (BMWi 2016).

The German Federal Ministries of Education and Research (BMBF) and Labour and Social Affairs (BMAS) also offer a wide range of support. Here, a central concern is the qualification measures necessary in the process of digitalisation. For this purpose, the BMBF has developed its own 'Digital Future' digitalisation strategy (BMBF 2020). The BMAS, has bundled these activities under Future Dialogues on Digitalisation and Qualification (BMAS 2020).

The German Federal Ministry of Economic Affairs and Energy is also focusing on the central issue of regulating platforms. This has resulted in a publication called White Paper Digital Platforms (BMWi 2017). This document presents proposals for a digital regulatory policy. The entailed proposals should help enable inclusive growth through investment and innovation based on fair competition, while ensuring individual fundamental rights and data sovereignty. In addition, the Ministry has established the Commission of Experts on Competition Law 4.0.

This has been the German government's reaction to the challenges of digitalisation. However, these reactions are oriented towards strong, previously successful policy patterns, and hardly do justice to the new dimension of structural changes concerned. The digital transformation of industry does not require incremental research advances, but ground-breaking breakthroughs in previously uncharted territory (Boston Consulting 2016; Roland Berger; Federation of German Industries 2015). Accordingly, much higher input is required per technology. Fixed research costs are rising.

The rising fixed research costs make it inevitable that certain technologies must be selected and committed to, despite the simultaneous high uncertainty about their success. Research funding that is entirely orientated towards the approach of "openness to technology" (characterised by not giving preference to certain technologies) is not sustainable in times of general technological reorientation. Even nations as large as the United States or China cannot invest sufficient research funds in all technology options to actually advance all of those technologies. This makes it all the more urgent for Germany not only to allow technological specialisation, but also to enter into international research alliances. For example, Germany could push for funding programmes to be more strongly geared towards key digital industrial technologies of the future.

The current processes of digitalisation are also leading to new forms of cooperation between universities, companies and the state (Gehl Sampath 2018; Kirchberger 2017). In Germany in particular, cooperation between application-oriented public and private research has traditionally been very pronounced. This has also been widely identified as an essential part of the success story of German industry. In the current phase of digital transformation, however, the roles of institutions are changing. The boundaries between research and application are becoming increasingly blurred. In many cases, companies generate the data that is both indispensable for basic research and concerns the marketability of products. The allocation of separate roles of universities for research and of companies for the marketing of innovations is no longer tenable.

At the same time, research lacks empirical evidence to support a probability of utilisation. In addition, individual companies can no longer afford the risks of implementation with rising fixed research costs. The German government should be able to bear these risks alone. Accordingly, the government must also invest much more in the implementation of research in digital products. Old concepts of pre-competitive research funding have had their day. If the government takes on a greater assumption of risk, it should also be remunerated by a direct share in profits. Accordingly, dormant state holdings in companies would have to increase.

At a glance – Digitalisation
Digitalisation requires a rethinking of essential elements of industrial policy strategies. Specialisations and European alliances in research have already become necessary. It seems most auspicious to focus of funding policy towards key digital technologies of the future. Strategic alliances must be formed between companies and government. The government must also invest much more in the implementation of research into digital products. The boundaries between pre-competitive research funding and investment aid will therefore become more fluid.

5.2 THE DECARBONISATION OF INDUSTRY AND CLIMATE CHANGE

In 2016, Germany made a commitment to align national policies with the Paris Climate Agreement and to significantly reduce greenhouse gas emissions. The agreement stipulates in binding international law that global warming should be limited to well below 2 °C compared to pre-industrial levels and that efforts be made to limit this to 1.5 °C.

At the EU level, the EU Commission's Green Deal envisages making economies greenhouse gas neutral by 2050 (EU Commission 2019b). This goal is linked to the hope that the path to climate neutrality can be a central innovation and growth driver for industry and the economy. However, the associated technological transformation poses major challenges, especially for energy-intensive sectors such as primary industry, which faces strong international competition (Lechtenböhmer/Fischedick 2019).

Germany has a broad canon of climate policy goals (SRU 2020). Aligning with the Paris Climate Agreement, the long-term goal is to achieve greenhouse gas neutrality by 2050. In 2016, as part of the Climate Action Plan 2050, the Federal Government adopted sector targets that set out emission reductions in the areas of industry as well as the energy sector, buildings and agriculture by 2030 (BMU 2019).

The industrial sector is responsible for 21 per cent of Germany's greenhouse gas emissions (2017, equivalent to 193 Mt CO_2 equivalent), which presents a comparatively large share next to the other sectors. Although the industrial sector has been able to significantly reduce emissions over the past 25 years from 283 Mt CO_2 equivalent in 1990 to 193 Mt in 2017, further emission reductions are needed. According to the Federal Climate Change Act, emissions from the industrial sector must fall to 140 Mt CO_2 equivalent by 2030. In order to achieve the long-term goal of making the economy as climate neutral as possible by the middle of the century, emissions must fall to 14 Mt CO_2 equivalent in 2050. The production of basic materials such as cement, steel and chemicals contributes to 16 per cent of European greenhouse gas emissions (Richtstein/Neuhoff 2019).

INDUSTRY CHALLENGES AND KEY POLICY INSTRUMENTS

The biggest challenge for German industry is, in addition to an increase in energy saving measures, to achieve further and more significant technological innovations for a shift away from fossil fuels (Blazejczak et al. 2018). This can only be achieved if production processes are quickly geared towards climate neutrality. For example, vehicle production must obtain the steel it needs from CO_2-free processes. This can be achieved by switching the operation of blast furnaces from coal to renewably sourced (green) hydrogen, for example. Since about 50 per cent of all blast furnaces are aging and will have to be replaced over the next few years anyway, now is the time is right to make them sustainable and climate-friendly. Green hydrogen will also be essential for the chemical industry and as a fuel for heavy goods vehicles, ships or aircraft in a climate-neutral economy. The automotive industry also has to change its production processes and move towards electric mobility in the individual vehicle sector, while climate-friendly drives will be required in the heavy-duty sector (SRU 2017). Extensive modernisation is thus urgently needed.

The central instrument for decarbonising the economy in Europe is currently the European Emissions Trading Scheme, which has so far not provided sufficient incentives for many options for reducing emissions (Kemfert et al. 2019; Neuhoff et al. 2016). It is therefore crucial that, in addition to placing a price on climate-damaging production through emissions trading (and possibly other instruments such as a CO_2 tax or a "climate contribution"), concrete government support is also provided for the development and introduction of sustainable, environmentally friendly technology. In addition, competitive disadvantages caused by a CO_2 price and the introduction of technologies that are initially not price-competitive must be cushioned in order not to burden companies that must stay internationally competitive and to avoid carbon leakage. At the same time, the revenue from a CO_2 tax could be used to finance climate-friendly investments and technologies (Neuhoff et al. 2016).

The opportunity to cultivate a competitive industry environment and promote Germany as a business location should also be seized through a more ambitious energy efficiency policy. Increasing energy efficiency is a response option for many energy-intensive industries that are affected by energy price increases. Even if there are technical limits, considerable efficiency potentials are still not being realised due to a number of different obstacles, as numerous studies have shown (SRU 2016). Clearly, there is a need for a long-term and integrated energy efficiency policy that is supported by binding goals. Therefore, existing policy instruments should be tightened, such as raising efficiency standards in Europe and Germany, introducing a tax reform geared towards climate protection, or improving financial incentives explicitly focused on efficiency. In addition, all measures should be coordinated within the framework of a coherent mix of regulatory standards, financial incentives, subsidies and advisory services (SRU 2016).

Building on the European Green Deal, an extensive reduction in greenhouse gases from primary industries is possible through appropriate linkages to circular economy. Material and product utilisation efficiency can enable considerable energy savings. In addition, electrification based on renewable electricity and green hydrogen can make an important contribution (Lechtenböhmer/Fischedick 2019).

A central element of the Green Deal is an integrated climate and industrial policy. This entails the development of an energy supply with renewable energies for primary industries, an adjustment of the European Emissions Trading Scheme through a minimum CO_2 price, the promotion of technologies for market introduction, as well as instruments for dematerialisation and increased circular economy (Lechtenböhmer/Fischedick 2019).

ENERGY COSTS AND COMPETITIVENESS

The energy costs for industry are of significant economic and energy policy interest, especially for energy-intensive sectors.

Energy prices, such as the global prices for oil and hard coal, are formed on the world market. Consumer prices vary due to different national taxation and price components. The pricing of gas and electricity also varies internationally. In a European comparison of industrial end-customer electricity prices, electricity costs for industrial companies in Germany are above the EU average. However, the different requirements for electricity price reporting that apply in the individual EU member states mean that it is not possible to make a proper comparison. (SRU 2016).

Electricity costs in Germany account for just under two-thirds of total energy costs in industry. In 2000, the share was only slightly more than half (BMWi 2014). The level of electricity prices is essentially determined by the burden of taxes, levies and charges, such as the EEG levy or grid charges. In relative terms, large electricity consumers generally pay significantly lower charges than small and medium-sized industrial companies, although these are only estimations due to a lack of transparency (SRU 2016).

Rising energy prices are often associated with declining competitiveness and are seen as being disadvantageous for industrial locations. However, this is only one factor among a number of other important criteria. A large number of studies show that Germany offers numerous advantages for industrial companies, such as a stable regulatory framework or a secure infrastructure, and Germany is ranked in an above-average position in global comparisons (SRU 2016).

Moreover, it is only in a few sectors of the economy for which energy is actually a central production factor. Energy costs are low for a majority of sectors, such as mechanical and vehicle engineering, with a magnitude of no more than two per cent of production costs (SRU 2016).

A more meaningful indicator than the energy cost burden is the unit energy cost. These are the costs of energy use per unit of gross value added (EU Commission 2014). Over the past 25 years, these have always been below the EU-27 average and at a similarly low level to the U.S. or the UK. These costs of energy use are significantly lower than those of competitors such as China, Japan, France or Italy (SRU 2016).

For energy-intensive companies, energy costs are a key competitive factor. They are therefore already supported by exemptions from energy levies and taxes in order to maintain international competitiveness (SRU 2016). The energy-intensive economic sectors of the manufacturing industry include basic chemicals, metal production, non-ferrous metals, foundries, earths, paper, and glassware. These sectors are responsible for a large part of industrial energy consumption and greenhouse gas emissions.

Since energy-intensive industry could come under pressure from international competition as a result of both CO_2 pricing and a switch to technologies that are not (yet) competitive in terms of price, political measures are important for compensating against this competitive disadvantage and to avoid carbon leakage risks (Neuhoff et al. 2015).

The amount of investment required for the long-term climate-neutral conversion of industry is considerable and can only be quantified to a limited extent. For largely CO_2-free industrial production alone, capital expenditure of up to 230 billion euros is expected by 2050 (Prognos AG/The Boston Consulting Group 2018). The Federation of German Industries (BDI) estimates the investment required to achieve climate neutrality for the entire German economy is around 1.5 trillion euro (BDI 2018). The estimates for necessary investments are therefore based less on current needs, than on the strategic projects realised to date (Belitz et al. 2020).

For investments in climate-friendly production processes in industry, the prices of the EU Emissions Trading Scheme (EU ETS) do not provide sufficient incentive since they are regarded as being rather moderate and volatile. In order to create more incentives for investments in climate-friendly production processes, innovative projects should be guaranteed fixed CO_2 prices within the framework of Carbon Contracts for Difference (CCfD). These are envisaged in both the Green Deal and the German Climate Change Programme 2030 and should be implemented and introduced ambitiously. Governments of European member states can guarantee a fixed price for companies that invest in climate-friendly technologies, so that CO_2 savings can be rewarded above the price of the EU ETS (Richtstein/ Neuhoff 2019). CCfD is concluded between the EU member state and investors on the basis of each specific project. The state side commits to pay out the difference between the EU ETS allowance price and the CCfD contract price if the allowance price is too low. The CO_2 price is agreed upon and guaranteed on a project-by-project basis. The investor, on the other hand, is obliged to pay if the certificate price is higher than the contract price (Richtstein/ Neuhoff 2019; Bach et al. 2020). Overall, there is a need for more certainty in the direction for investments, especially in primary industries, particularly because of the long investment cycles of industrial process technologies. This is crucial to avoid so-called stranded investments. However, the fact that the necessary change processes sometimes require more radical innovations, pose a number of economic and political challenges. Mobilising the urgently needed investments will only succeed if the government takes an active role. This involves both the planning and financing of important infrastructures and the formation and promotion of alliances for the development of concrete key technologies. The focus must therefore on:

- the expansion of renewable energies and decentralised, digitalised distribution grids (smart grids);
- the expansion of electric vehicle charging infrastructures;
- the promotion of hydrogen technology and, if necessary, other power-to-gas approaches;
- the promotion of electric mobility technologies;
- the development of industrial CCS technologies.

There is the threat that the Corona crisis will perpetuate weak investment in industry (Belitz et al. 2020). Weak private investment can therefore only be overcome if investment demand is stimulated by short-term financial support, while targeted government involvement reduces existing medium-term market risks. Path dependency and possible lockins of climate-damaging investments, such as fossil-based internal combustion engines or new fossil energy infrastructures, must be comprehensively avoided (Fischedick 2020).

At a glance – Decarbonisation
Climate protection and the energy transition are opportunities for industry, which in turn requires reliable framework conditions to cope with the enormous need for innovation and investment. This includes reliable emission reduction targets, the expansion of renewable energies and investment alliances for new technologies. The necessary investments can only be triggered by massive governmental support, both by means of suitable regulatory frameworks and concrete financial aid.

5.3 DEVELOPMENTS IN VALUE CHAINS

TRANSNATIONAL PRODUCTION SYSTEMS IN CORE SECTORS OF GERMAN INDUSTRY

A number of studies have recently examined the question of whether, or to what extent, a change in shortening and re-regionalisation of supply chains has taken place or whether such a development trend may gain (further) significance in the future. One starting point is the observation that the dynamics of globalisation slowed down about ten years ago, beginning in a close temporal connection with the global economic crisis of 2008/09. In the two decades prior to this period, both the share of global trade in total goods production and global direct investment by companies abroad saw a significant rise; from 2008 onwards, these developments transitioned into stagnation (Felbmayr/Görg 2020; UNCTAD 2020). This was also reflected in the significantly lowered number of new relocations by German production companies abroad in the same roughly ten-year period from 2008, while cases of relocation back to Germany remained stable (Kinkel/Jäger 2017).

Among other factors attributed to countering globalisation are technological developments in the areas of production processes and logistics as well as politically influenced factors. These political factors include the rise of nationalism and protectionism, which can lead to growing uncertainties (WUI 2020) for world trade, but also goals of sustainable development such as climate protection or the avoidance of exploitation. In the wake of the Corona pandemic, there are indications that point to a further increase in uncertainty about the stability of global trade relations and an increasing need for resilience in supply chains. A study published for the United Nations Conference on Trade and Development, (UNCTAD) in July 2020 sees a consequence of these influences as being a decade of transformation in international production systems (UNCTAD, 2020).

Since, by international standards, German industry is particularly integrated in international supply, sales relationships and value chains (Flach et al. 2020), it is obvious that such developments could become especially relevant for Germany. If re-regionalisation were to be linked to a return of production to Germany, this could, as it were, automatically lead to a strengthening of domestic industry, which could perhaps be supported by the German government through technology promotion with an affinity to re-regionalisation, such as robotics. However, the abovementioned developments in core sectors of German industry come up against very different models of globalisation: Vehicle manufacturing, mechanical and plant engineering, the chemical and pharmaceutical industries, and the electronics industry, all of which are strongly export-oriented, differ greatly in terms of their integration into international value chains and the associated strategic options.

For example, the manufacture of motor vehicles and their components is an example of continually increasing specialisation along the vertical value chain. In the automotive supply industry in particular, this specialisation goes hand in hand with the fragmentation of the individual production steps regarding both national locations and companies. Since the 1990s, automotive manufacturers (OEMs) have been increasingly transferring value added to suppliers in the course of outsourcing processes; many of these suppliers have exploited labour cost advantages in the emerging economies of Central and Eastern Europe by taking their production or purchasing from suppliers outside of Germany (Schwarz-Kocher et al. 2019). As a result, there was an increase in the import of supplier parts to Germany. At the same time, the German supplier industry has significantly increased its exports to other regions of the world. Furthermore there has also been increasing pressure for German companies to build up their own production capacities in North America and China as well, in order to supply the German automotive plants of in those locations with uniform quality and just as flexibly as in Germany. This is likely to significantly limit the prospects for a further increase in exports of subcontracted parts in the future. Moreover, in addition to the current recession, the German automotive industry is also being hit by the decarbonisation of transport in the transformation to electric mobility (as well as the even-more belated transformation of other transport sectors, such as logistics and public transport vehicles), for which it is surprisingly ill-prepared given long-standing demands for more environmentally friendly technology. With regard to the structure of the value chains, this even raises the question of whether the automotive industry in Germany or in Europe as a whole is competitive in core technologies such as battery and fuel cell technology.

A different pattern of integration into international value chains and serving customers on the world market can be seen in German mechanical and plant engineering: With a broad diversification, this sector shows a high share of foreign sales. With a share of around 16 per cent of world machinery exports, Germany was the world's most important export country in 2019. However, German machine manufacturers also supply their customers to a large extent through their own locations and company holdings in foreign target markets. The high importance of a company's foreign locations in mechanical engineering is a consequence of the production of customised solutions strongly tailored to individual customer needs as well as the ability to carry out after-sales service.

Overall, it can be seen that Germany's most important research-intensive industrial sectors – mechanical engineering, the manufacture of motor vehicles and motor vehicle parts, the electrical industry and the chemical industry – have been particularly successful over the last few decades in exploiting the advantages of various global production sites in the course of specialisation within the sectors and/or along the value chains. The basis for the successes in the foreign markets was above all a top position in the areas of technology and product quality.

However, the individual sectors benefit in different ways from the various advantages that the internationalisation of supply and value chains and of their own production sites can bring: the use of cost advantages (especially in labour costs), proximity to customers and the use of economies of scale have different weight as motives for globalisation in the individual sectors. Proximity to competent technology providers in the field of electronics and semiconductor technology is obviously playing an increasingly important role. The fact that competent partners and suppliers in this area must increasingly be sought outside Europe is now also calling into question the leading technological position of German motor vehicle manufacturing and possibly also of mechanical engineering in the future.

For the chemical industry characterised by particularly high capital intensity and strong economies of scale in production, setting up production abroad has involved particularly high investments (and risks). Here, a re-regionalisation in the sense of a shift back to Europe is not conceivable. Rather, it is true for various productions that, following greenfield investments to open up markets, some of the most modern processes can now be found in other regions of the world. In this situation, future challenges must be addressed such as decarbonisation that require major leaps in technology and a change in upstream and downstream value chains (see below). This can and should be the focus of an industrial policy that can (still) build on the fact that knowledge carriers and technological competence in companies are still largely concentrated in Germany or Europe.

THE INFLUENCE OF DIGITALISATION

Increasing digitalisation in production processes and logistics could lead to re-regionalisation. Digitalisation has the potential to increase productivity, thus decisions to localise certain production steps in the course of realigning value chains can be less strongly geared to wage cost differences in the future. Empirical evidence for the relevance of automation and digitalisation on the location decisions of industrial companies are already evident: For example, German companies manufacturing simple products that can be easily automated have only been relocated abroad half as often as German companies manufacturing complex products that involve a higher proportion of manual work for which wage cost differences are more significant. In addition, industrial companies that use digital technologies with high intensity less frequently cite wage cost differences and more frequently customer proximity as a motive for moving production off-shore (Kinkel/Jäger 2017).

This makes it all the more important to promote digitalisation in industry, also with a view to the change in value chains. BMWi monitoring of the digitalisation of the German economy attributes a digitalisation level of 45 per cent to industry in 2018 (BMWi 2014), which would indicate a lot of potential. Especially advanced processes such as artificial intelligence have only been used in a small proportion of companies so far. Overall, digitalisation therefore still offers considerable opportunities to reduce production costs and increase the quality of service. The individualisation of products up to the production of individual series and batch size 1 lead us to expect advantages for production close to sales and thus (also) for Germany as a production site, which can also revitalise the production of consumer goods (e.g.: clothing, furniture, bicycles).

However, there are also countervailing effects: For example, low-wage countries are now increasingly also introducing cost-cutting rationalisation measures using digital technologies. Supply chain management will also benefit from advancing digitalisation, so that improvements in delivery performance and a reduction in transport costs can also be expected (IPA 2020). Due to these ambivalent effects of digitalisation it is difficult to assess and control the consequences of its state support on the spatial structure of value chains. It is clear that digital technologies are increasingly being used in all operational as well as strategic corporate functions that (also) optimise value chains and will determine efficiency, which in turn affects competitiveness. This offers new opportunities to promote the re-regionalisation or relocation of industrial production if, for example, the existing landscape of research institutions in Germany can be made more accessible to small and medium-sized industrial companies.

THE INFLUENCE OF SUSTAINABLE DEVELOPMENT ON GLOBAL VALUE CHAINS

Measures to promote sustainable development can lead to changes in location structures and value chains in a number of different ways. Either adverse or beneficial effects on the competitiveness of industry may result if such measures are applied in a differentiated manner in different world regions or states. So far, this has been mainly discussed with regard to the ecological aspect of sustainability, such as the reduction of greenhouse gas emissions: Here, governmental regulations such as the European Emissions Trading Scheme can certainly affect location structures and the flow of goods through additional costs for companies, as production and emissions threaten to migrate to countries outside the EU (carbon leakage) along with an increase in imports from non-EU countries not affected by the regulation or a loss of exports.

So far, however, carbon leakage has been successfully prevented by appropriate EU protective measures; for the potentially particularly affected sectors or goods, no structural decline in production or exports or an increase in imports has been discernible since the start of emissions trading. In connection with the introduction of a national emissions trading scheme, the German Federal Government also plans to protect particularly affected industries from carbon leakage effects. However, the current regulations to reduce greenhouse gas emissions from industry have so far only had a limited effect in terms of climate protection in most relevant sectors; accordingly, significant effects on location structures and value chains are not to be expected. The current goals for reducing greenhouse gas emissions in industry (see Section 4.2) can only be achieved through far-reaching changes in production processes and input materials, and thus in value-added structures and input chains.

The decisive factor would then not be regional differentiations, but the question of which technological options for reducing greenhouse gas emissions will prevail. For example, for the steel industry, the industrial sector with the highest absolute greenhouse gas emissions in Germany, the use of carbon capture and storage (CCS) is possible in primary steel production while maintaining the prevailing blast furnace technology; in this case, imported coking coal could continue to be used and the current value chains could be supplemented with processes of CO_2 storage or the use of captured CO_2 (CCU). Conceivable – and also currently being developed by steel companies in Germany – is a fundamental change in technology away from blast furnaces and towards direct reduction plants in which hydrogen is used instead of coke. This could be produced from imported natural gas or domestically as green hydrogen via electrolysis from regeneratively generated electricity. Green hydrogen could also be imported from North Africa, where it may be cheaper to obtain due to the advantages of solar power generation despite the additional transport. Under certain circumstances production facilities could also be relocated to those countries that can produce hydrogen at low cost.

For other energy-intensive industries with high greenhouse gas emissions, different technologies for reducing greenhouse gas emissions are also conceivable in a similar way, with different consequences for domestic and cross-border value chains; in addition to steel production, the production of cement, basic chemicals, lime, glass and paper as well as mineral oil processing are addressed here. Across these different industrial sectors, the production of hydrogen and other operating substances from renewably generated electricity (power-to-gas) and – at least to a certain extent – the use of captured CO_2 as an input for downstream value-adding stages (CCU) will probably play an important role and lead to corresponding changes or additions in the value chains.

For the development of industry in Germany, a crucial factor will be to what extent renewable energy production becomes possible through the creation of sufficient domestic capacities and to what extent hydrogen made from renewable energy can be imported. With regard to domestic electricity generation, for example, restrictions on onshore wind power utilisation due to extended distance regulations and bottlenecks in the electricity transmission grids must be critically assessed. The opening up of North Africa as a supplier of green hydrogen is, on the one hand, obvious, but in the countries concerned this is tied to preconditions such as political stability, which are currently only fulfilled to a limited extent.

With regard to value chains based on power-to-gas technologies, there is likely to be considerable development potential in cross-sector system solutions that enable sector coupling. Such system solutions – similar to existing isolated power generation technologies such as combined-cycle gas turbines or wind turbines – may offer considerable export opportunities in the future. Therefore, from an industrial policy perspective, there is much to be said for taking on an internationally pioneering role in climate protection.

Thirdly, beyond carbon leakage effects and the transition to different technologies, interactions between climate protection measures and the development of value chains are also conceivable in connection with CO_2 emissions from transport. In this way, effective climate protection measures could make international transport over the long distances between world regions more expensive and contribute to a re-regionalisation of value chains within the world regions. This reduction in flows of goods between world regions would then presumably be accompanied by an increase in intracontinental trade flow and transport (such as between countries within Europe, or between the US and Mexico) or partly intra-national trade flow and transport (such as within China). Within given regions, important drivers of 'regional globalisation' are the existence of very similar markets and comparable demand preferences, as well as the still existing differences in important costs, such as labour. Reduced intercontinental trade flows that are predominantly based on shipping, would thus be offset by growth in intraregional trade and associated transports predominantly using heavy goods vehicles (HGVs).

Such a shift would possibly result in only small reductions in greenhouse gas emissions due to the approximately tenfold higher greenhouse gas emission factor per tonne-kilometre for HGV transports, so that overall measures for the sustainability of transports will probably not be an important driver for a re-regionalisation of value chains. In addition, attempts to include air transport outside the EU in the ETS, at least to the extent that the EU is a destination for foreign airlines, have in fact failed, as have similarly designed efforts to include maritime shipping in emissions trading with this expanded approach.

The proposal for a supply chain law in Germany can be interpreted as a similar attempt with a view to securing social standards (such as human rights) to establish sustainability principles outside EU regions.[6] This should establish the responsibility of local (here: German) producers for the entire supply chain (see also BMWi 2020h). But even in this example, the arduous course of the discussion shows that sustainability measures with effects beyond EU borders are at best very difficult to realise in the current political climate. Therefore, it is not to be expected that such measures will trigger decisive impulses for a change in global value chains.

THE EFFECTS OF THE CORONA PANDEMIC: RECESSION OR IMPETUS FOR MORE RESILIENT VALUE CHAINS AND TECHNOLOGICAL MODERNISATION?

The severity of the current economic crisis caused by the Corona pandemic has highlighted vulnerabilities within international value chains: In many industrial plants, production

6 As part of UCL Mission Oriented Innovation and Industrial Strategy (MOIIS), the Supply Chain Due Diligence Act (LkSG) was adopted by the Bundestag on June 11, 2021 and will come into effect on January 1, 2023.

could only be continued to a limited extent or at times not at all due to a lack of input materials and parts; car production in Germany and the rest of Europe even came to a complete standstill for about two weeks. China's exports to Germany of the products and components for automatic data processing that are used as preliminary products in many industrial sectors, fell by 22 per cent in the first quarter of the year compared to the previous year (Görg/Mösle 2020). Since then, both policy makers and academics (Blum et al. 2020) have been discussing whether the resilience of supply chains to crises should be increased through targeted industrial policy measures.

The first thing to note is that it is currently difficult to assess how the crisis will affect the industry in the medium to long term. Structural effects on value chains of a longer-lasting nature may result from the fact that certain companies cannot survive the losses in sales resulting from the Corona crisis despite state aid measures such as short-time work, for example because their capitalisation was already low before the crisis.[7] Such risks are likely to increase with further lockdowns. Companies in the automotive supply industry should be considered in this context since this industry is in some cases considered to have weak margins (Schwarz-Kocher et al. 2019) and has now also become the focus of special aid measures. Manufacturers in industry segments that are expected to take a particularly long time to recover should also be considered. This is to be expected, for example, in aircraft construction; in this area in particular, suppliers often have a high degree of specialisation of individual companies within the value chains in certain production processes and technologies, such as the manufacture of ultra-light components that are rarely needed in other fields of application, making it difficult to switch to other markets.

In this respect, it is first to be expected that companies will try to reduce existing risks in their own operations as well as in their upstream and downstream value chains. This will likely involve taking structural measures by realigning themselves in the choice of suppliers, investments abroad or the choice of locations for production. This likelihood is illustrated in the results of a survey of around 3,300 German companies (around half of which were industrial companies) operating abroad in June/July 2020. According to this survey, 60 per cent of the companies interviewed want to reduce their foreign investments and 38 per cent are looking for new suppliers, of which about one third each are looking for new suppliers in Germany and the rest of the EU. Even if, in many cases, measures that companies cannot implement ad hoc will not be implemented as the crisis progresses or comes to an end, it can also be seen that structural effects on value chains and location structures on a larger scale are certainly within the realm of possibility. Past examples also show that changes are being made in supply chains, e.g.: to reduce dependence on individual suppliers; for example, car makers have been changing their procurement strategies since 2016 following the dispute between the VW Group and the supplier Prevent.

It is expected that when facing upcoming decisions, companies will be putting greater importance on resilience in the event of a crisis. In the short term, this can be mainly achieved by increasing stockholding and replacing just-in-time deliveries. In the long term, consideration will likely be given to in-sourcing of certain production steps and a switch from single sourcing with individual suppliers to multiple sourcing with several suppliers.
Such measures are associated with different opportunities:

- Increased stockholding is relatively easy to implement in sectors with relatively uniform series in high numbers or quantities (such as vehicle manufacturing or chemicals). At the same time, with innovation-dynamic preliminary products (such as semiconductors), the risks of devaluation of stocks increase, while in the case of high customer-related individuality of end products (typically in mechanical engineering) a build-up of stocks is difficult to realise. Companies in the mechanical and plant engineering sector could therefore react with more consistent common part strategies and the realisation of customer-related individual quality for more complex modules, thus improving conditions for stockholding.
- A switch from single to multiple sourcing comes with additional costs due to a higher effort for certifications and ongoing supplier management and a deterioration of economies of scale (e.g.: due to increased tool requirements). However, suppliers with locations in different regions of the world can be used in this way, so that there can be a clear effect in the form of greater resilience. Incidentally, suppliers of preliminary products can also profit from this in the same way if this leads to customer growth. The implementation of such strategies would thus also be bound to a change in location structures, for example, by relocating production back to Germany or the EU.

Changes in location structures through in-sourcing and multiple sourcing can be realised all the more easily and cost-effectively, if the possibilities of digitalisation are more consistently used in both production and the management of supply chains (see above). Therefore, building greater resilience can be effectively supported by promoting such technology. This may include additive manufacturing processes (3D printing), the increased use of robots, or the use of solutions for maintenance, and troubleshooting over long distances. There is also great opportunity in the digital mapping of products – including all production-relevant parameters ('digital twin'), the digital replication of production processes along the supply chain, the collection of production-relevant data through innovative sensor technology and the establishment of data platforms for all participants in the supply chain. The introduction of such advanced and partly prerequisite technologies should also be promoted in small and medium-sized industrial companies. The replacement of goods deliveries by other forms of transaction is also conceivable. In this way, concepts of decentralised manufacturing can be implemented in 3D print shops distributed around the world, which are supplied by

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7 During the global pandemic in 2020/202, Germany's short-time work scheme (*Kurzarbeit*) has meant that employers have been able to reduce their employees' working hours instead of laying them off. With this tool the German government normally provides a 60 per cent income 'replacement rate' (more for those with children) (IMF 2021).

companies over long distances with the necessary print programmes, e.g.: in order to produce required spare parts directly in the vicinity of the customer. Licensing production by third parties in the target markets is also an option.

In many cases, this will be a trade-off between efficiency and resilience. The latter has so far often played a subordinate role in the fundamental structuring of value chains and has emerged as a 'by-product' of quality assurance measures. In this context, the accepted price for resilience will also be (very) limited in the future. In those areas where efficiency-oriented suppliers are in direct competition with companies that have created more resilience in their structures at additional cost, procurement decisions will probably often be made ad hoc in favour of the cheaper offer. Conversions to multiple sourcing structures have already been carried out in individual cases, proving that hedging against risks can definitely gain importance as a guiding principle for companies in the design of value chains.

Against the backdrop of the Corona pandemic, the new opportunities that can arise from the further development of robotics and 3D printing in the design of value chains and the localisation of production can be all the more attractive (see above). The associated potential for shifting value creation steps back from Asia to Europe – either to be closer to external suppliers (near-shoring) or to the company itself (in-sourcing) – could open up the possibility for 'resilient efficiency'. That being said, a rapid development in this direction is hardly to be expected, not only because of existing supply contracts, but also because in the current crisis, the willingness to make the investments required for relocations and automation will initially be limited, even with low interest rates. The creation of value-creation structures with higher resilience is therefore also likely to be slowed down by the low investment momentum. This makes measures that promote investment in the above-mentioned opportunities to improve resilience all the more important. Even if it were accompanied by a relocation of production back to Europe, whether Germany would actually benefit from a dismantling of global value chains is another question altogether. The same reasons that speak for a shift back to Europe in the manufacture of preliminary products also apply to a shift in the manufacture of end products to their target markets, which today are often served by exports; in vehicle manufacturing and also in other sectors, this trend of production in the sales markets by German car manufacturers already began some years ago. On the other hand, with regard to the localisation of production within Europe, it must be noted that more and more steps within the value chains can now also be organised in Central and Eastern Europe at lower labour costs.

In the context of the debate on resilient value creation structures, in the future, a special case may be those sectors that are considered essential for the provision of public services. In the light of the pandemic, the first thing to consider here is the production of medicines and medical equipment. The interim ban on the export of face masks in Germany and other EU states, or the state's participation in the vaccine manufacturer CureVac in the context of the U.S. courtship over the relocation of this company to the USA, have made it clear that state decision-makers see this area as being relevant to the provision of public services in a new way. Especially in the case of medicines that need to be developed specifically for the treatment of certain diseases, stock-holding larger quantities is ruled out as an option for creating more resilience. Firstly, it is more important to develop vaccines, medicines and remedies against new pathogens and diseases as quickly as possible and to produce them locally in sufficient quantities. This requires high research capacities, especially in the short term, which can stabilise the pharmaceutical industry in Germany and Europe that is already extremely research-intensive. In addition to the current Corona virus, there are already other tasks in the health sector, such as the fight against multi-resistant germs by intensifying the development of antibiotics. Secondly, at least part of the vital generic production should be located in Germany or Europe in order to avoid supply bottlenecks.

The automotive industry probably also requires special attention, albeit for quite different reasons. This involves both the major car manufacturers and the broad, deep and very diverse landscape of supplier companies. There are already signs that the economic slump caused by the Corona pandemic is also acting as an accelerator for the structural upheaval associated with the technological transformation towards electric mobility, hydrogen and e-fuel drives (in the heavy-duty sector), autonomous driving and ride sharing. In addition, the declining demand for supplier parts, which is also structural in the case of parts for the powertrain of vehicles with internal combustion engines, is putting pressure on prices and further fuelling the relocation of production to nearby neighbouring Central and Eastern European countries with their low labour costs. While the large car manufacturers and larger suppliers are benefiting from the fact that vehicle sales in China seem to be recovering quickly, many smaller supplier companies that are heavily dependent on the European sales market are facing profound problems: They have often had to make do with low profit margins in the past and are suffering from a lack of capital resources for investment in new products in the industry's greatest structural upheaval. It will be important here to promote the development of companies towards new products and production processes, which will obviously be oriented towards electric mobility. Here, beyond actual vehicle construction, gearing infrastructure towards electric mobility can also be envisaged as a goal for promoting transformation processes.

At a glance – value chains
The trends towards digitalisation, decarbonisation and increasing resilience, may affect various factors that lead to a re-regionalisation of value chains in the future. This will not automatically strengthen production in Germany for all sectors. Therefore, industrial policy should specifically respond to the different impacts of these three trends on individual industrial sectors and help address future challenges posed by new technologies and the requirements of climate protection. This concerns, for example, the decarbonisation of production processes that are associated with considerable initial investments and whose competitiveness only emerges in the context of a comprehensive market ramp-up.

5.4 THE INFLUENCE OF A NEW NATIONALISM AND PROTECTIONISM

The increasing stagnation of globalisation and the corresponding effects on international value chains is also reflected in key indicators of political globalisation governance. These are measures taken by states that lead to a change in the relevant framework for economic exchange. While tariffs played a major role as an instrument in the 1930s when there was a sharp decline in international trade links, today this is a broad mix of different non-tariff barriers to trade and investment. These include economic sanctions, which are increasingly being applied, or exclusions of foreign suppliers based on security policy, as decided by the USA and discussed in Germany with regard to equipment for 5G mobile networks against the Chinese supplier Huawei. An important indicator with regard to a more protectionist-motivated framework is also the handling of foreign direct investment.

In general, worldwide direct investments follow the stagnation trend of the globalisation index. Politically relevant regulations on foreign direct investment have been evaluated according to whether they tend to have an opening or a closing effect. These evaluations show that in the past 20 years there has been no general increase in the number of new regulations and opening regulations are still about three times more common than closing ones (UNC-TAD 2020). Nevertheless, in recent years there has been a clear trend in favour of more closing regulations. In addition, the number of disputes over direct investments between states and (potential) investors has significantly increased. This tendency towards a more protectionist climate is mainly driven by industrialised countries (UNCTAD 2020). This is especially the case especially in Europe where fears of a sell-out of domestic industry are repeatedly heard with regard to direct investments from abroad. A similar 'political mood' is also evident in other instruments for shaping globalisation, such as the use of non-tariff trade barriers or preferential agreements with selected countries instead of applying general 'most-favoured-nation' treatment. While the Trump administration's measures in the US play a special role in this, many of these measures are currently being continued by the Biden administration and there has also been a general trend in this direction for some time (see the Obama administration's 'Buy American' initiative in 2009) – as well as in other industrialised countries.

The political rationality of protectionism is based on the fact that largely open world trade can be seen as a classic prisoner's dilemma. In the process, profits result from cooperation on the basis of the theory of comparative trade advantages as long as all parties play along. The (initial) opting out of individual states is initially rewarded, insofar as, for example, domestic companies are protected by tariffs and imports are substituted by domestic production. However, when the other actors follow suit, this leads to a situation that is often significantly worse in the end for all participants than the initial situation of global cooperation, because trade and investment flows are reduced and therefore also reducing the cooperation gains of the international division of labour.

In this respect, a free trade system and thus globalisation in general is a fragile construct that requires considerable trust. Exiting this system is mainly rational when a short-term (political) success is sought and it is assumed that the temporary favourable domestic effects will be relatively large, for instance due to the specific size and structure of the domestic market in question. These points could apply with regard to the U.S., although analyses suggest that the U.S. was also negatively affected by the Trump administration's rounds of tariff increases against China and the EU, with growth losses of over 0.3 per cent (Deutsche Bundesbank 2020).

In addition, structural problems in world trade frameworks make a protectionist exit from globalisation easier. Thus, the WTO system is only really capable of acting with the consensus of all member states. After the de facto failure of negotiations on more fundamental adjustments to the rulebook, which essentially consists of the GATT regulations of the 1950s, in the Doha Round (ongoing since 2001), there has been a widespread stalemate in regulations. Instead of reform, there is an increasing exploitation of exceptions to WTO rules.

Preferential agreements that refer to Art. 24 GATT are of particular importance in this context: These preferential agreements between individual states or groups of states do not establish a global system, but lead to the exclusion of 'all others' if the most-favoured-nation principle is circumvented. These are often the means used in local or regional policies, and sometimes justified with developmental ambitions. Against this background, open protectionism or exclusively bilateral international treaties are only a consistent continuation of the exploitation of WTO weaknesses. In addition, conflicts between cultural, political or social concerns and WTO regulatory proposals (cf. the disputes over the Transatlantic Trade and Investment Partnership (TTIP)) have led to a broad public discrediting of WTO regulations. On the whole, however, WTO weaknesses are probably 'facilitating circumstances' rather than core reasons for an increase in protectionism – after all, much of the hyper-globalisation took place within the framework of the GATT, which was still much weaker as a set of rules.

Confidence in the economic success of globalisation grew over several decades that began in the late 1970s and saw a surge in the early 1990s with events such as the transformation of Eastern Europe, which was tested over decades, similar developments in Latin America to some extent and, last but not least, the rise of China. These successes had their scientific and political basis in (new) neoliberalism, especially in Latin America and Eastern Europe. Economic theory and economic policy in this period, especially in these regions, was characterised by elements that focused on free economic activity with regard to trade between states, the withdrawal of the state from a formative economic policy and the testing of market competition, even in the area of money supply.

At the latest with the economic crisis of 2007/2008, confidence in an economic policy that relies only on market forces was severely shaken. Moreover, the crisis could essentially only be adequately combated by an interventionist economic policy. This may also have made the path towards protectionism easier in many places: Protectionism generally became more acceptable – albeit certainly with different national response patterns – and was driven by the perceived threat of countries like China catching-up.

It is obvious that a continued expansion of protectionist measures in the relationship between the USA, China and the

EU would tend to restrict the possibilities for exporting finished products to markets outside the EU as well as backward- and forward-interlinked value chains, and such a development would negatively affect Germany in particular due to the high export performance and strong international value-creation linkages of its domestic industry. Even short-term gains, for example, through tariff restrictions as countermeasures and the resulting import substitution, do not seem imaginable or amount to a positive overall effect for Germany and probably the entire EU and should therefore at best be considered only for tactical negotiation reasons.

In perspective, the EU may be faced with the choice of whether it wants a closer relationship with the US or with China. If one disregards socio-political and cultural aspects and looks at such a situation from a German or European perspective solely in terms of the functionality of international value chains, it must be said that the USA will not be replaceable as a trading partner in the foreseeable future due to its overwhelming importance in semiconductor technology and among the providers of the internet-based platform economy. This is all the more true since semiconductor technologies and certain elements of the platform economy in particular are of great importance for digitalisation in industry – especially in Germany's core sectors such as automotive and mechanical engineering. China's attractiveness as a particularly dynamically growing sales market, on the other hand, continues to be diminished by difficulties in gaining free access to this market (even though improvements have been implemented in this regard) and other problematic practices in the wake of Chinese industrial policy. At the same time, China's role as a highly efficient production site with low labour costs can, in principle, also be taken on by other states, partly also within Europe.

Insofar as the necessity of a choice between a close relationship with the USA or with China must indeed be assessed as a realistic scenario, the first conclusion to be drawn from this would probably be to 'mirror' the most important advantages of these trading partners elsewhere if possible. Thus, for example, the semiconductor industry and the development of strategically important segments of the internet-based platform economy such as cloud services in Europe would become possible candidates for a strategic industrial policy and, depending on a further intensification of trade conflicts, also with the goal of strategic autonomy. From this perspective, the use of the new potentials of digitally supported networking, automation and robotics to realise efficient and cost-effective value chains within Europe and Germany also takes on strategic importance.

In any case, an increasingly protectionist climate between the major world regions would make it even more necessary to focus on Europe's development options. This can refer both to the EU's internal market and to the relationship between the EU and its eastern, south-eastern and north African neighbours. There is undoubtedly great potential or need for economic development here. With regard to these neighbours, however, it must be said that the prospects of economic cooperation are currently obstructed by many political problems such as human rights violations and wars, a lack of democracy or migration. The de facto freezing of accession talks with Turkey is a particularly striking case in this respect.

Nationalism and protectionism at a glance

German industry is particularly hard hit by the increasing protectionism of important EU trading partners. Germany imposing protectionist measures of its own hardly promises. At the same time, a successful antidote. Rather, the strengths of the trading partners concerned, such as the semiconductor industry or the internet-based platform economy, should be built up elsewhere, preferably in Europe. The attainment of strategic autonomy in individual key technologies may also become a necessary goal as trade conflicts increase. In addition, efforts to develop efficient value chains would need to focus more on options within the EU and in its neighbourhood. For economic reasons alone, the relationship with the USA will be more important than with China in the foreseeable future; if necessary, it must therefore be given preference in terms of industrial policy.

6

APPROACHES TO A NEW INDUSTRIAL POLICY STRATEGY

In almost all developed economies, a need for industrial policy action arose when industry was rediscovered as an anchor of stability after the economic crisis in 2009. The European Commission developed an economic policy programme package for a European industrial renaissance in early 2014. In 2019, Germany's industrial policies gained stronger orientation through initiatives introduced by the German Minister of Economic Affairs. In 2020, this industrial orientation was included in the EU's new industrial strategy.

The scientific community reacted very differently to the revitalisation of industrial policy. Some were sceptical and negative about the announced stronger state involvement. Criticism was levelled in particular at the promotion of 'national champions'.

It was feared that competition between companies would suffer from the steering effect of government favouring these 'national champions.'

Another part of the scientific community also saw the possibility of aligning industrial policy much more closely with socio-political goals. The demand for a 'mission orientation' became louder.

With the crisis triggered by the Corona pandemic, the discussion on the fundamental direction of industrial policy has been pushed into the background. Economic policy is in emergency programme mode. In Germany, bridging assistance is granted for many sectors and a wide variety of business structures. From solo self-employed artists to Lufthansa, the state provides financial support without, however, exerting any strategic influence on corporate policy.

Aside from these emergency programmes, in fact the direction of industrial policy has changed little since the announcement of the new Industrial Policy Strategy 2019. The focus is on a passive industrial policy, characterised by openness to technology and pre-competitive promotion. Prime examples of this are general financial incentives to increase innovation activities. Such incentives have currently been massively increased in Germany through the introduction of tax incentives for corporate R&D expenditure. At least the first signs of a more strategic orientation of German innovation and industrial policy can be seen in the Agency for Disruptive Innovation (SPRIND), which is currently being set up. The agency's first goal is to identify and promote research ideas with leap innovation potential. To this end, idea competitions have been launched for cutting-edge projects with the goal to transfer ideas from R&D to application that have a duration of three to six years. It is not yet clear whether and how this can concentrate activities and resources on a few radical innovations, including the investments to implement them. The comprehensive National Hydrogen Strategy introduced in the summer of 2020 goes one step further, announcing not only research funding but also funding and subsidies for private investments in infrastructure and production facilities in this innovative technology area.

A first application case for a real reorientation of German and European industrial policy, on the other hand, is the introduction of the instrument of Important Projects of Common European Interest (IPCEI). So far, two such international projects have been launched with German participation. One of the projects relates to the field of microelectronics, the other to battery cell production chains. In total, 5 billion euros of public money from different countries and 11 billion euros of private investment from different companies are to flow into both projects. Technology and industrial policy are used in a coordinated manner across the entire value chain.

But are these initial approaches to a reorientation of industrial and technology policy suitable to sufficiently support the German economy in coping with the tasks of the future, arising above all from digitalisation, decarbonisation and the changed conditions of globalisation?

Thesis 1: The state must take a more strategic approach, concentrate funding on selected future digital technologies and invest more than before in the implementation in new digital products!
As a new basic technology, digitalisation is fundamentally changing production conditions in industry. Rising fixed research costs make it inevitable for companies and states to choose and specialise in certain technologies. In times of general technological reorientation, research funding that is exclusively open to technology is unsustainable for individual countries. This makes it all the more urgent for Germany not only to allow new technological specialisations, but also to enter into international research alliances. Current processes of digitalisation are also leading to new forms of cooperation between universities, companies and government. The separation between application-oriented public research and private investment in commercial implementation is no longer tenable. Even individual large companies can no longer cope with the increasing risks involved in implementation. The state alone should be able to noticeably mitigate these risks. Accordingly, the state must also invest much more in the implementation of digital products. Old concepts of merely pre-competitive research funding are often not sufficient for this purpose.

Thesis 2: Without active governmental action, mobilising the necessary investments in climate-friendly industrial technologies will not succeed. The state must provide financial support for necessary investments and drive the development of important infrastructures and alliances for the development of concrete key technologies and their market ramp-up.

In 2016, Germany committed to aligning national policies with the Paris Climate Agreement and significantly reduce greenhouse gas emissions. For industry, it is clear that, in addition to increased energy-saving measures for energy saving, further and considerable technological innovations must be realised for a shift away from fossil fuels. The investment sums needed for the long-term climate-neutral conversion of industry are enormous. For largely CO_2-free industrial production alone, investment expenditures of up to 230 billion euros are expected by the year 2050. Primary industries especially need directional security for investments due to long investment cycles of industrial process technologies. This is crucial to avoid stranded investments. Since the necessary change processes sometimes require 'radical' innovations, the mobilisation of the urgently needed investments will only succeed if the government takes an active role. In addition to suitable regulatory framework conditions, this involves both the planning and financing of important infrastructures and the formation and promotion of alliances for the development of concrete key technologies, right up to financial support for necessary private investments and the creation of sales markets for sustainably produced products.

Thesis 3: The resilience of supply chains and the achievement of strategic autonomy in selected future technologies are becoming new tasks for industrial policy.
Today, the structures of global industrial value chains are characterised by a high degree of spatial disintegration based on international division of labour specialisations in certain industrial sectors over different stages of value creation. This structure is the result of a long phase in which industrial companies in developed industrialised countries have either switched their sourcing to suppliers in low-wage countries or established their own production sites in other countries. In recent years, however, the dynamics of globalisation have noticeably slowed down. The reasons lie in the areas of production processes and logistics as well as politically influenced factors; the latter include increasing nationalism and protectionism. In the wake of the Corona pandemic, reference is also made to a further increase in uncertainty about the stability of global trade relations. In the context of the geopolitical competition between the USA and China, achieving technological leadership in selected future technologies is also becoming a central industrial policy goal. In order to avoid dependencies and not just be a pawn in geopolitics, Europe must therefore achieve strategic autonomy in central industrial key technologies. If industrial policy is going to contribute to resilience in supply chains, vulnerabilities in the supply chains must first be identified and then concepts for overcoming them must be developed. This involves both securing partnerships developed in research projects, for example, and concrete financial support in individual cases.

Thesis 4: Private investment weakness can only be overcome if medium-term market risks are also reduced through targeted governmental involvement. A suitable instrument for linking technology and investment policy are concrete technology-oriented investment funds. With a clear commitment to the selected technologies, such targeted investment support programmes could contribute to building technology leadership.

The challenges posed by digitalisation, decarbonisation and the changing conditions of globalisation are intensified by the economic consequences of the Corona pandemic. This is only marginally about creating resilient supply chains for pharmaceutical and medical technology products. The global pandemic has also triggered a macroeconomic investment crisis. In Germany alone, equipment investments in the second quarter of 2020 are almost 30 per cent below the previous year's level. In other EU countries, these effects from the Corona pandemic are even worse. A tried and tested instrument for stimulating investment demand that has met with broad consensus among economists is an improvement in depreciation conditions. The current economic stimulus package provides a temporary authorisation of declining balance depreciation for Germany. However, such tax incentives come to nothing if, as is currently the case, many companies have no prospect of making any profits at all. Private investment weakness can only be overcome if medium-term market risks are also reduced through targeted governmental involvement.

There is a lot of evidence to suggest that the German government needs to be more involved in the restructuring of the capital stock, not less, which is where a strategic industrial policy plays a key role. This would provide the opportunity to combine technology and investment policy. Modern economies like that of the Federal Republic of Germany depend on being at the forefront of the global innovation process. Germany must therefore also focus on promising radical innovations. Such future technologies are highly risky. However, this also means that failures in state technology policy must be tolerated, just as they are in the private sector. Conversely, wait-and-see and risk aversion are associated with the danger of preventing important technological developments, since a certain mass is often required to set certain innovation processes in motion.

A suitable instrument for linking technology and investment policy are concrete technology-oriented investment funds. With a clear specification of the selected technologies, such targeted investment support programmes could generate new partnerships between companies and the state.

These partnerships could then contribute to maintaining supply chains and building technology leadership. Further EU-wide partnerships should be sought, as has proven prudent in the promotion of the establishment of value chains in battery cell production.

The initiation of individual technology-oriented investment funds should be as transparent as possible – also to limit the influence of lobbyists. Technology-oriented investment funds must be clearly delineated to ensure subsequent evaluation. The funds must not be understood as mere economic promotion and certainly not used to maintain technologically obsolete productions. Funds must report on their failures as openly and transparently as they report on their successes. This serves to legitimise risky state investments in the future.

Since society provides extensive resources, it is essential that a formative technology policy is oriented towards societal goals and values. Possible societal consequences must be taken into account in the evaluation and selection of technology-oriented investment funds. In this process it is imperative that inhibitive administrative effort and lengthy decision-making processes must be avoided. An abstract top-down system of an all-encompassing mission-oriented industrial policy, ranging from goal setting to technology identification to instrument selection, is therefore not practicable for this purpose.

Technology-oriented investment funds should initiate and support cooperative projects, networks and clusters. Compared to the funding of individual projects or general financial support, this has the advantage that the desired spill overs between the relevant stakeholders involved are already built in. Measures are required to ensure the dissemination of research results to the scientific community and outside companies. In addition to the general welfare gains that can be achieved, a considerable part of the additional profits of the participating companies should be returned to the taxpayers through a claw-back mechanism. Suitable forms for this purpose are direct silent participations in companies, but also charges on increases in value, such as those levied on landowners for infrastructure measures.

List of abbreviations

ARPA	Advanced Research Projects Agency
ARPA-E	Advanced Research Projects Agency-Energy
BDI	Federal Association of German Industry
BMAS	Federal Ministry of Labour and Social Affairs
BMBF	Federal Ministry of Education and Research
BMWi	Federal Ministry for Economic Affairs and Energy
CCfD	Carbon Contracts for Difference
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
DARPA	Defense Advanced Research Projects Agency
DGB	German Trade Union Confederation
EFI	Expert Commission on Research and Innovation
EFSI	European Fund for Strategic Investments
EIC	European Innovation Council
EKF	Energy and Climate Fund
EU ETS	EU Emissions Trading Scheme
R&D	Research and development
IARPA	Intelligence Advanced Research Projects Agency
IPCEI	Important Project of Common European Interest
ISCF	Industrial Strategy Challenge Fund
KfW	Reconstruction Loan Corporation
AI	Artificial intelligence
SME	Small and medium-sized companies
MIC	Made in China 2025
MOIIS	Mission-driven innovation and industrial strategy
Mt	Mega tonne
NIP	National Hydrogen and Fuel Cell Technology Innovation Programme
NWS	National Hydrogen Strategy
OEM	Original Equipment Manufacturer
SprinD	Agency for Leap Innovations
TTIP	Transatlantic Trade and Investment Partnership
WTO	World Trade Organization

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