

OECD Studies on SMEs and Entrepreneurship

Fit-for-Future Manufacturing SMEs

Effective Policies for Transformation



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EFFECTIVE POLICIES FOR TRANSFORMATION

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Foreword

In recent years, the global manufacturing landscape has been profoundly affected by megatrends such as digitalisation, automation, the emergence of a low-carbon economy and the transition to energy-efficient processes, the reconfiguration of global supply chains, as well as increasing geopolitical uncertainty and economic volatility. These transformations are creating both new opportunities and complex challenges, particularly for small and medium-sized enterprises (SMEs), which are vital to industrial ecosystems but often face more onerous and distinct barriers in adapting to these rapid changes than larger firms.

This report aims to explore how global megatrends are reshaping the economic landscape for manufacturing SMEs, and how policy can better support their ability to anticipate, adapt and respond.

Focusing on three strategically significant manufacturing sectors – automotive, electronics (semiconductor) and machinery – the report examines how these trends are unfolding across industries. It analyses the differentiated challenges and opportunities SMEs face, depending on their roles within shifting supply chains and emerging technological ecosystems. The report also examines how governments are responding through both broad industrial strategies and SME-specific policy initiatives.

Drawing on in-depth case studies and policy mapping across selected OECD member countries – France, Germany, Japan, Korea and the United States – the report presents detailed country profiles that examine national manufacturing landscapes, SME readiness and key policy measures to support their transformation, including broad industry-level policies and targeted support for SMEs. Building on this analysis, the report identifies emerging trends and policy insights, underscoring the need for integrated, multi-layered industrial strategies that recognise and empower SMEs as central actors in shaping future-ready manufacturing systems.

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Executive summary

Manufacturing plays a central role in the global economy, with SMEs contributing significantly across value chains

Manufacturing is a cornerstone of global economic value creation, directly contributing around 16% of global GDP and 14% of employment. Beyond these direct contributions, the sector generates wider economic impact through extensive upstream and downstream linkages, technological diffusion and productivity-enhancing innovation spillovers. Within this ecosystem, small and medium-sized enterprises (SMEs) play a crucial role. They operate across value chains – from supplying essential raw materials to producing components and finished goods – supporting both domestic industries and international trade. While large corporations typically bring branded products to the market, SMEs are integral to the production and distribution processes (e.g. as retailers and service providers) that underpin global manufacturing. In 2023, SMEs accounted for around 41% of value added and 57% of employment in the manufacturing sector, on average across the OECD.

New industrial strategies have emerged in response to megatrends and recent shocks

The manufacturing landscape is being reshaped by three powerful forces: digitalisation, policy and consumer incentives for more resource-efficient production methods, and a stronger appreciation of factors and policies that support long-term competitiveness, including reduced vulnerabilities to geopolitical risks and supply chain disruptions. Technological advances are transforming operations, as factories and supply chains increase uptake of digital tools such as data analytics and artificial intelligence (AI), as well as broader technologies that enable automation and data sharing across interoperable ecosystems. At the same time, a combination of emerging environment-related regulations, high energy costs and adoption of more resource-efficient production processes have also resulted in transformations in manufacturing value chains. In addition, the shifting patterns of trade in recent years have also increased tendencies to shorten supply chains. The COVID-19 pandemic accelerated these trends, as have tariff uncertainties.

While these changes present new opportunities, SMEs often face barriers to adapting and profiting from them, constrained by limited internal capacity and limited access to external strategic resources, such as finance, technology, talent and knowledge networks.

New industrial policies need to factor in SME realities

New industrial strategies, intended to strengthen industrial competitiveness, economic resilience and sustainable growth, have typically focused on large firms, often resulting in SME-specific needs being sidelined or insufficiently integrated into policy frameworks. At the 2023 OECD Committee on SMEs and Entrepreneurship (CSMEE) Ministerial Meeting, Ministers emphasised the need for industrial policies that

embed SME perspectives from the outset, not least to support their participation in supply chains during a period of significant change in international trade patterns.

Understanding sector-specific transformations

This report takes a granular and sector-specific approach to enhance understanding about manufacturing transformations and policy responses. It focuses on the automotive, electronics (semiconductor) and machinery sectors, which are at the forefront of digital and low-carbon transformations, and in which SMEs contribute significantly to value added and employment. For example, as input providers in the automotive sector, micro firms and SMEs generate around 58% of the value added. Transformations unfold differently across the three industries, resulting in distinct supply chain dynamics and priorities for SME policy:

- **Automotive SMEs** face structural shifts due to the rise of electric and autonomous vehicles. Many SMEs in internal combustion engine supply chains must either pivot their capabilities or exit the sector. Substantial opportunities emerge for SMEs and start-ups offering information and communication technology (ICT) services, software and connectivity-related components. However, uncertainty about regulations and strategies by original equipment manufacturers (OEMs), including trends towards vertical integration, affect SME investment and adaptation.
- **Semiconductor SMEs** operate in a highly capital- and skill-intensive environment with high entry barriers. However, niches such as fabless design and resource-efficient chip innovation offer growing opportunities, if SMEs can overcome barriers like access to intellectual property (IP) talent, and financing. The ongoing reshoring of semiconductor production is also creating new opportunities. Reshoring efforts and the development of local ecosystems also open doors for SMEs, particularly in areas where they already have a foothold, such as materials, tooling and back-end services.
- **Machinery SMEs** are navigating the convergence of hardware and software, with increasing demand for smart, connected and energy-efficient equipment. New technologies like augmented and virtual reality (AR/VR), digital twins and 3D printing are transforming product development, with benefits for SMEs producing in small batches. Despite these opportunities, many SMEs lack digital capacity and investment readiness, especially to shift from hardware to service-based models.

Across all sectors, the pace and scale of transformation, combined with SME inherent challenges, highlight the need for sector-specific and SME-tailored strategies to unlock new opportunities and address transition bottlenecks. While new industrial strategies are emerging across many countries, including all those covered in this report, dedicated SME support often remains limited. Many policies still rely on assumed trickle-down effects from broader industrial competitiveness measures. However, there is growing recognition of the need for approaches that are better adapted to SME challenges and opportunities – not only to help SMEs overcome persistent barriers such as financing and skills shortages, but also to maximise synergies between major industrial policies and SME-specific interventions, given their critical role in value chains.

Drawing on sectoral and country-level analysis, this report identifies emerging SME-responsive industrial strategies. Key features of these approaches include:

- **Ecosystem approaches that foster structural linkages between SMEs and key players in local and global supply chains, including large firms and research organisations.** These include taking into account SME specificities in the funding of industry-led R&D consortia – such as through the development of SME-friendly “plug-and-play” solutions – and supporting SME-enabling regional clusters by improving access to hubs, shared infrastructures and advanced technologies through targeted financial incentives.

- **Place-based support that addresses SME skill gaps and promotes knowledge and technology transfer, such as through advisory services and SME-targeted training programmes, often implemented by regional actors and networks.** These initiatives align SME capabilities with local industry needs and regional specialisations, helping SMEs better integrate into local supply chains and innovation systems.
- **Simplified access to industrial policy programmes and support, in particular funding and advice.** This includes reducing administrative complexity, streamlining application procedures, minimising access costs, as well as designing programmes that accommodate diverse needs and characteristics of SMEs, with flexible implementation mechanisms that adapt to varying business sizes, sectors and stages of development.

1 Synthesis of findings

This chapter synthesises the findings of the report on how digitalisation, the transition to low-carbon and energy-efficient production, and geopolitical and supply chain disruptions are reshaping manufacturing SMEs, with a focus on the automotive, electronics and semiconductor, and machinery and equipment sectors. It highlights how the pace and nature of these transformations differ across sectors, creating distinct opportunities and challenges for SMEs, including in access to finance, skills, technology and markets. Drawing on policy approaches in France, Germany, Japan, Korea and the United States, the chapter assesses how industrial strategies address SME needs and finds that support often remains secondary to measures targeting larger firms. It identifies emerging approaches to more SME-responsive industrial policies, including ecosystem-based R&D and cluster initiatives, place-based skills and networking support, and simplified access to tailored finance and advice.

Introduction

The manufacturing industry is undergoing profound disruptions and transformations, driven by global megatrends, notably accelerated digitalisation and the emergence of low-carbon and energy efficient production models. Recent economic shocks, geopolitical tensions and trade policies have further compounded uncertainties, accelerating reconfigurations in global trade and value chains. These shifts present mounting challenges for the industry. To remain competitive, especially for SMEs, it is crucial to understand how these transformations are impacting production processes and reshaping the drivers of competitiveness across different sectors. This insight is equally vital for policymakers aiming to design effective and forward-looking industrial strategies.

As detailed in the report, these transformations pose common challenges to manufacturing SMEs, like skills, finance and technology gaps. However, they unfold differently across manufacturing subsectors, which results in distinct priorities for SMEs and start-ups. In the automotive sector, the shift towards clean, connected, and autonomous vehicles represents an existential challenge for SMEs producing internal combustion engine components, many of which need to adapt their capabilities to electric vehicle (EV) value chains or pivot to new industries to meet the evolving demands of original equipment manufacturers (OEMs). In the semiconductor sector, historically characterised by long and fragmented global value chains (GVCs) – with chips commonly crossing borders up to 70 times during production (Global Semiconductor Alliance, 2020^[1]) – geopolitical tensions, trade policy changes and national industrial policies are driving supply chain reconfigurations. While the industry's capital- and skill-intensity creates high entry barriers, opportunities open up for innovative SMEs and start-ups in niche segments like energy-efficient chip design, specialised components supply (e.g., raw components like wafers, or etching machines) or service maintenance. In the machinery sector, SMEs face growing product complexity driven by the rapid advancement of digitalised machines and systems. Accelerating digital adoption and organisational change is crucial for machinery SMEs to capitalise on the growing opportunities in smart manufacturing, as well as address rising material costs and price-eroding competition, especially from large global competitors that manufacture comparable products.

The varying speeds and magnitudes of transformation, along with inherent challenges faced by SMEs, highlight the necessity of integrating broad framework policies with sector-specific and SME-targeted policies. To design and implement effective SME policy support in the manufacturing sector, it is crucial to gain a granular understanding of SME-specific and sector-specific challenges and opportunities stemming from these profound transformations. This report focuses on specific sectors and supply chains – automotive, electronics (semiconductor) and machinery – which, given the prominent role of SMEs, offer distinct yet exemplary insights for SME policy development.

This synthesis of findings is structured as follows: the first section summarises the impact of key trends on selected manufacturing subsectors and implications for SMEs. The second section offers insights on broad industrial policies and targeted instruments developed by selected OECD countries to assist SMEs in navigating these transitions. The third section highlights key features of industrial policies in the manufacturing sector that actively include SMEs, as emerging from the experience of the OECD countries examined in the report, namely France, Germany, Japan, Korea and the United States.

Global megatrends impact manufacturing sectors at varying speeds and intensities, shaping distinct challenges for SMEs

The impact on the manufacturing sector and its SMEs

Automotive

In the automotive sector, SMEs play a prominent role in the multi-tiered supply chains centred around carmakers. Tier 1 suppliers, the linchpins of the car-making ecosystem, aggregate detailed components from a broad network of Tier 2 and Tier 3 suppliers, mainly SMEs that contribute specialised parts and materials. In fact, SMEs are present in different segments of the automotive value chain, from raw material, component and module provision (upstream) to retail, service and maintenance (downstream), accounting for 58% of value added in the sector.

With the advent of electric and autonomous vehicles, this supply chain landscape is undergoing radical transformation. With consistently rising global sales of electric vehicles (EVs), traditional internal combustion engine components are being gradually phased out in some countries. Batteries and electric motors have emerged as the new power generation systems, complemented by an array of sensors and software.

The shift from internal combustion engines to electric powertrains demands significant investments in new technologies and specialised skills, hence the need to mobilise substantial financial resources. In Germany, in 2023, automotive suppliers allocated 28% of their total investments to e-mobility, despite it generating only 10% of profits. Access to finance represents a major constraint to the transition, compounded by regulatory uncertainty that affects OEM strategies. Evidence from Korea highlights that a large number of suppliers, especially smaller ones, are not ready to transition, due to limited financial resources but also lack of knowledge about target areas. Uncertainty about regulation and supply chain reconfiguration results in reluctance by SMEs to invest in the new technologies and skills needed for the transition.

Despite significant progress in the technological, legislative, and commercial development of autonomous driving, particularly triggered by breakthroughs in artificial intelligence (AI), SMEs face similar uncertainties and high entry barriers. However, these advancements also present substantial opportunities for SMEs and start-ups in the ICT sector, as well as sensor and hardware providers. The fierce global competition between established car manufacturers and big tech companies entering the autonomous driving space further fuels these opportunities but also generates risks related to increased vertical integration. To navigate this competition, large OEMs are acquiring expertise to bridge gaps in software capabilities and build data infrastructure, often through acquiring start-ups, establishing subsidiaries, or forming alliances. Big tech companies, which tend to internalise autonomous driving technologies based on their own hardware and software capabilities, are also acquiring start-ups in key technological areas to enhance their development. This trend towards vertical integration of supply chains presents risks of marginalisation for many SME suppliers. Consequently, SMEs, including those offering ICT services, software, and connectivity-related components, increasingly depend on the strategies of OEMs and Tier 1 suppliers for collaboration.

Electronics and semiconductor

The electronics sector – and its core, the semiconductor sector – is characterised by highly fragmented and globally interdependent value chains. The sector produces a foundation for digitalisation, powering everything from smartphones to data centres, and its supply chains span diverse regions and firm sizes. While the dominant players in the sector are large firms, SMEs play a distinct role in the ecosystem, particularly in upstream activities such as supplying raw components like silicon wafers and photomasks, as well as specialised equipment like etching and chemical vapor deposition equipment.

The rapid advancement of AI and other emerging technologies has sharply increased demand for semiconductor chips, driving significant growth across the sector. Global semiconductor sales doubled between 2012 and 2022 and are projected to reach USD 1 trillion by 2030. Growing demand for chips in critical sectors such as drones, robotics, telecommunications, and aerospace, has also elevated the strategic importance of semiconductors. In response, many governments launched industrial policies for reshoring and localisation of products, aiming to build localised ecosystems, the U.S. CHIPS Act and EU CHIPS Act representing notable examples. These shifts may carry important implications for global supply chains, potentially reshaping sourcing patterns and investment strategies.

This expansion of demand for semiconductors is not limited to cutting-edge chips dominated by major players. It also creates fragmented and niche markets where SMEs can compete effectively – for example, in custom chips, energy-efficient processors, or specialised packaging. The rise of the fabless model (chip design without owning a fabrication facility) has lowered entry barriers, enabling start-ups and SMEs to enter the market through design-focused innovation, where agility and innovation are more important than scale. The creation of local and regional ecosystems through reshoring efforts also offers potential for local SMEs to integrate into restructured supply networks, especially in materials, tools, and back-end processes, where many SMEs are already active. For SMEs, opportunities exist particularly in low-power chip solutions, energy-efficient architecture, and materials alternatives, where their agility and smaller scale offer an advantage over larger firms bound by legacy infrastructure.

These trends create new opportunities for SMEs to expand their customer base, but only if they can develop strong technological expertise and clear strategic direction. With limited capacity for full-scale R&D and often insufficient managerial resources, SMEs also face persistent barriers like capital constraints, restricted access to resources, such as proprietary IP and design tools, and power asymmetries in global partnerships. As countries race to position themselves as global semiconductor powerhouses, national industrial policies often prioritise large players, and fail to capitalise on SMEs' agility advantage, offering them limited support to fully participate in the evolving semiconductor value chains amid a rapidly changing global landscape.

Machinery and equipment

The machinery and equipment sector is a central pillar of industrial value creation, supplying a wide range of products to other sectors of the economy. SMEs represent the vast majority of companies in the sector, accounting for 44% of total turnover on average across the OECD in 2022, and as high as 60-75% in countries like Korea, Portugal, Italy, and Spain. Medium-sized firms are especially prominent, often delivering specialised intermediate components.

However, the SME share of turnover in this sector has shown a downward trend, falling from 50% in 2010 to 48% in 2015, and further to 44% in 2022. This mainly reflects rising capital intensity and scale economies amid technological transformations and increased system complexity. With structural change driven by digitalisation and connectivity, demand in this sector is shifting from stand-alone hardware to integrated solutions involving the Internet of Things (IoT), AI, and data analytics. For instance, in construction machinery, predictive maintenance enabled by sensors and connectivity is becoming standard, with companies increasingly offering digital service packages alongside equipment. The increasing customer

demand for automated and connected solutions is reflected in projections for the smart manufacturing market, which is expected to grow by around 13% annually until 2030.

Furthermore, the sector is playing a crucial role in driving energy efficiency across the entire manufacturing sector, as its products shape energy and material use in a range of industries. Evidence from Germany suggests that a growing share of machinery manufacturers' customers are requiring solutions that improve energy efficiency and minimise product losses. To address these changing market demands, companies in the sector are adapting their product portfolios, expanding into areas such as hydrogen fuel cells, energy storage systems, recycling solutions, and drive components for the global wind gearbox industry.

Adopting smart manufacturing presents diverse opportunities for SMEs. New technologies like AR/VR, digital twins, and 3D printing are transforming product development, allowing rapid prototyping and reduced costs, especially beneficial for SMEs producing in small batches. For example, virtual simulation allows SMEs to test machinery systems without costly trial-and-error cycles. Moreover, IoT-enabled platforms – exemplified in this report by Italy's TRE-E Smart Lifts consortium and Germany's Oculavis GmbH – demonstrate how collaborative digital ecosystems can strengthen SME service delivery, data sharing, and customer engagement.

Despite these opportunities, many SMEs remain focused on hardware production and face challenges in transitioning to service-based or digitalised business models. The cost of digital transformation (including IT infrastructure, system integration, and workforce training) remains a significant barrier to SMEs. A 2022 survey of US companies shows that, although 75% of manufacturing SMEs recognise the strategic value of smart technologies, only around 50% are willing to invest in them. Skill shortages, particularly in automation, AI, and cybersecurity, further limit SME adoption. Research from Korea also highlights path dependency, as SMEs with low initial technology adoption are less likely to succeed in digital diversification, widening the capability gap with larger firms.

SMEs are increasingly expected to design more energy-efficient, durable, and recyclable machines, yet often with limited resources to do so. In some countries, recent energy price hikes have compounded the challenge, particularly in energy-intensive processes like forging and machining. While digitalisation offers mitigation tools, such as predictive maintenance and optimised energy use, these solutions again require significant upfront investment, which remains a recurring barrier for many SMEs.

Economic shocks and geopolitical tensions highlight the critical need for manufacturing SMEs to accelerate the transformation

Recent crises have exposed the heightened vulnerability of manufacturing SMEs to economic shocks and supply chain disruptions. The impact of disruptions is amplified for SMEs due to multiple factors including their limited financial reserves, which can provide a buffer against rising costs for essential inputs such as energy and raw materials. This vulnerability became evident in several countries following the sharp increase in energy prices triggered by Russia's war of aggression against Ukraine. Many firms, especially in European countries that are heavily reliant on Russian oil and gas, faced skyrocketing energy costs. This posed substantial challenges to the competitiveness of manufacturing firms and highlighted the fragility of global supply chains.

Long-term economic transformations are increasingly being shaped by geopolitical developments and the shifting comparative advantages of firms, regions, and countries, thereby catalysing the emergence of new industrial strategies across countries. Since the global financial crisis in 2008, governments have gradually embraced industrial strategies to promote their national economic growth and productivity. This marks a significant departure from the historical reluctance surrounding such strategies since the 1970s (OECD, 2022^[2]). The COVID-19 pandemic and disruption of global trade further underscored the actual and potential risks associated with long and fragmented GVCs. In response, across world regions, countries

have intensified efforts to build more resilient supply chains, increasingly prioritising proximity and strategic autonomy over the cost-efficiency once offered by distant delocalisation.

In recent years, major industrial policy initiatives have emphasised the localisation of supply chains as a means of strengthening industrial resilience. In practice, these strategies often include tax incentives for domestically produced machinery components, encouraging firms to maintain or establish production facilities within national markets. The CHIPS Acts in the United States and Europe adopted a similar approach, aiming to expand semiconductor manufacturing capacity within national or regional borders and, in doing so, reshape supply chains in this strategically important sector.

As governments implement structural reforms to enhance industrial competitiveness and reduce supply chain vulnerabilities, some SMEs have proactively adapted to mitigate risks by diversifying their supplier networks – particularly by sourcing from geographically closer partners. Evidence from France shows that, over 2020-24, 31% of SMEs have experienced supply chain disruptions. Among those affected, 61% responded by either increasing inventory levels or diversifying their supplier base. Insights from Japanese SMEs reveal that businesses with advanced digital infrastructure were better equipped in handling disruptions. These businesses leveraged data for real-time inventory management and explored alternative sourcing strategies more effectively. These examples underscore the critical role of digital adoption and diversification strategies in strengthening SME resilience against external shocks.

Despite growing awareness of supply chain vulnerabilities, many SMEs across OECD countries remain underprepared for disruptions. For example, 2022 evidence from Korea reveals that only 2% of SMEs had established strategies to manage supply chain risks. This lack of preparedness is often rooted in structural barriers such as limited awareness, constrained resources, and the complexity of navigating foreign regulations. These challenges hinder SMEs from developing effective risk management strategies in response to strategic dependencies and geopolitical tensions. Moreover, major industrial policies integrate SME realities to a limited degree. The following section explores the implications of these policies for manufacturing SMEs and examines more targeted support instruments designed to enhance their future readiness.

Policy priorities and approaches vary across sectors and countries, with SME support often limited

Industrial policies to strengthen manufacturing sectors reflect countries' differences in economic structures, strategic priorities and institutional capacities, as illustrated through selected cases in this report. Across countries, various targeted measures have been designed to support SMEs, recognising their role in achieving strategic objectives. However, in most cases industrial policies mainly target and engage large enterprises, and place limited emphasis on addressing the specific needs of SMEs, although differences emerge across sectors. The report investigates policy strategies and their specific implications for SMEs across the three sectors of focus, illustrating emerging approaches to better align industrial and SME policies.

Automotive

In the automotive sector major policies address the development and adoption of electric and autonomous vehicles. A variety of complementary regulatory and policy instruments focuses on the ongoing shift from traditional internal combustion engine-centred value chains to the production of electric and low-emissions vehicles. In Europe, climate regulations, such as the EU's "Fit for 55" package, which targets a 55% reduction in greenhouse gas emissions by 2030, have introduced new requirements for the road transport sector. In particular, the revised EU CO₂- emission standards for cars and vans set fleet-wide targets through 2035, creating a regulatory framework for zero- and low-emission vehicles. These measures are

complemented by pollutant-focused regulations, such as the Euro 7 standards, which set limits on exhaust and non-exhaust emissions. Beyond the EU, other OECD countries have also set mandatory targets for zero-emissions vehicles within timeframes ranging from 2025 to 2050.

To achieve these targets, many countries have adopted price-support measures, in particular purchase subsidies for EVs in the EU, to make EVs more price competitive as compared to traditional internal combustion engine vehicles. Norway first introduced these measures in the 1990s, and, as of 2024, 15 EU countries, along with some non-EU countries, such as Korea and Japan, had similar policies in place. In the past, the U.S. federal government has offered tax credits instead of direct purchase subsidies. In addition, most OECD countries have put in place public investments to foster the EV charging infrastructure, as well as complementary support measures, such as providing free parking for EVs in inner cities.

Despite variations in the effectiveness of EV subsidies and tax incentives across countries – and recent policy rollbacks in some regions – EV sales have steadily risen at the global level. The report underscores the importance of policy consistency in enabling OEMs and SMEs to adapt their business models to this industry evolution, through long-term strategic investments. For example, Germany’s sudden termination of its EV environmental bonus led to significant drops in EV sales, production slowdowns and planning uncertainty for suppliers. This case illustrates the risks associated with abrupt policy changes, which can result not only in direct financial losses, but also in undermined long-term investment confidence across the supply chain.

While regulatory frameworks in the area of autonomous driving are still evolving, with road management regulations, accident liability, and insurance policies yet to mature, countries like the U.S., China, and Germany are advancing in autonomous driving regulations. Major automobile-producing countries, including the U.S., EU countries, and UK, are also implementing funding policies to support autonomous driving vehicle technology. These policies create opportunities for innovative SMEs and start-ups, particularly in sectors like ICT, AI, and cybersecurity.

A variety of targeted policies have been implemented across countries to help SMEs navigate mega-trends and integrate into future automotive value chains. These policies include funding for collaborative R&D projects, preferential loans, and grants for investment, as well as initiatives to enhance skills and foster networking opportunities. Notable examples are France’s 2030 five-year investment plan, which allocates funding for innovation and supports SME involvement in digital and low-carbon projects for future vehicle production. Automotive sectoral strategies, in particular in EU countries, are increasingly adopting an “ecosystem approach” to strengthen collaboration between OEMs and suppliers through R&D networks. A notable example is Germany’s Catena-X project that encourages the development of standardised data solutions by industry-led consortia to improve SME integration into automotive value chains, particularly in increasingly data-driven production settings. Strategies also aim to lower investment barriers for SMEs. For example, Japan’s Mikata project provides capital investment subsidies and consulting services tailored for SMEs to innovate and produce future vehicle parts. These policies are further supplemented by specialised workforce training programmes, such as France’s “Compétences et Métiers d’Avenir”, which helps workers reskill for roles in digital and sustainable transformation. Additionally, state-run programmes in Germany offer SMEs targeted advice, assist with funding applications, and promote collaboration through regional transformation networks. By combining financial support with advisory services, networking, and training, these policies aim to ensure SMEs have the resources and guidance necessary to remain competitive in the rapidly evolving value chains of the automotive industry.

Electronics and semiconductor

Recognising the critical role of the electronics and semiconductor sector in driving technological progress, several countries have implemented large-scale strategic initiatives. National-level policies and support packages have emerged with a strong focus on reshoring production to strengthen supply chain resilience

and reduce dependency on foreign semiconductor manufacturers. Over the past decade, around 2 500 industrial policy interventions targeting advanced technologies – including semiconductors and their critical inputs – have been implemented globally. The US CHIPS Act was enacted in 2022, and the EU CHIPS Act was introduced in 2023, with the aim to double the EU's semiconductor production by 2030. Similarly, in recent years, Japan, Korea, and China have implemented national master plans and regulations, supported by large-scale public and private investments. While all “CHIPS Acts” share the core objective of enhancing supply chain resilience through reshoring, key differences exist. For example, in the U.S., new federal funds have been allocated specifically for semiconductor initiatives, alongside tax incentives to attract investment. In contrast, the EU has been channelling funds from existing programmes and operates a more complex and lengthier approval process, compared to the more streamlined U.S. system.

There are different financing mechanisms to support the highly capital-intensive semiconductor sector, with a trend-shift from traditional tax incentives for R&D activities to direct subsidies to expand domestic production. This shift is exemplified by large-scale public funding for new domestic production facilities under the U.S. CHIPS Act and the Important Projects of Common European Interest (IPCEI) framework within the EU CHIPS Act. These programmes aim to leverage substantial private investment in line with the scale of public co-funding. Alongside the establishment of advanced fabs, IPCEI includes specific financing and networking support for SMEs and start-ups, recognising their role in the broader semiconductor ecosystem.

Despite a decreasing weight in recent years, traditional tax-incentives – once accounting for approximately 90% of total budgetary support to firms in the semiconductor industry, based on 2014-2018 data (OECD, 2019^[3]) – continue to play an important role. The main players in the sector, namely the U.S., EU, Korea, Japan, China, Chinese Taipei, and Singapore all have tax incentives in place, with varying funding amounts allocated for either investments in semiconductor manufacturing equipment or R&D activities. Complementary instruments to promote R&D include research grants, training initiatives and public-private partnerships, which are exemplified by cross-country projects under the EU's Horizon Europe. As a highly R&D-intensive sector that operates through globally distributed supply chains, government policies have also focused on technology transfer through FDI policies. To build a thriving domestic semiconductor ecosystem, several countries have adopted cluster policies inspired by successful experiences, such as Chinese Taipei's high-tech clusters. These geographically concentrated ecosystems bring together research, manufacturing, design, and assembly, enabling shared infrastructure, access to talent, and co-development of supply chains.

While innovative local SME suppliers benefit from large-scale investments via increased demand for components for semiconductor production, SME-targeted support in this sector remains limited. Some innovative SMEs are able to address specific market needs, such as by developing energy-efficient chips, thereby benefiting from tax incentives and emissions regulations impacting the growing semiconductor sector. However, despite some targeted initiatives like SME-focused subsidies in some EU countries, high entry costs, complex technological requirements, and skills barriers in the sector often result in the sidelining of SMEs, while large firms continue to receive the bulk of government funding. This imbalance underscores the need for a policy design and implementation that includes SMEs more actively. This report highlights emerging initiatives that aim to better integrate SMEs and start-ups into the broader semiconductor ecosystem. These programmes often focus on connecting SMEs with larger firms, fostering knowledge transfer, and facilitating access to critical infrastructure and funding. As a case in point, Korea provides SMEs with preferential financing, targeted R&D support, and enhanced access to foundry services through partnerships with larger players. These efforts are also complemented by prototyping services to reduce development costs and lower market entry barriers for emerging players.

Machinery and equipment

Sectoral strategies in the machinery industry focus on digitalisation, automation, energy-efficiency, and strengthening domestic supply chain resilience. In particular, strategic initiatives are in place to help companies adapt to evolving component ecosystems – characterised by increasing software integration, and growing demands for maintenance and lifecycle management. Key policy frameworks such as U.S. National Strategy for Advanced Manufacturing, Korea’s I-Korea 4.0, the EU Digital Strategy, and Germany’s Platform Industry 4.0 exemplify these trends. Additionally, machinery-specific regulations, such as the EU Machinery Regulation 2023/1230, address these shifts. The regulation broadens the definition of safety components to include digital and software elements and introduces cybersecurity requirements to protect safety functions from digital threats. While the regulation applies broadly, it offers simplified conformity assessment for certain machinery types, and reduced fees for SMEs, easing administrative burdens and helping especially smaller manufacturers meet market entry requirements more easily.

As the machinery sector is closely linked to other manufacturing industries – particularly automotive and semiconductor – major policies targeting these industries significantly impact the sector and its strong base of medium-sized companies. This has been the case, for instance, of the various CHIPS Acts that have implemented in many countries, and that have contributed to increased demand for advanced semiconductor manufacturing equipment. Financial instruments such as tax incentives, grants, and preferential loans can help machinery SMEs invest in the production of energy-efficient equipment and advanced technologies. Major initiatives that have been implemented over the past decade include the U.S. Inflation Reduction Act (IRA), the EU Green Deal Industrial Plan, and EU measures under the Recovery and Resilience Facility (RRF). Some policy initiatives emphasise supply chain resilience, targeting the upgrading of local production capacity to reduce reliance on foreign suppliers. This is the case, for instance, of Japan’s “Initiatives for Ensuring the Stable Supply of Machine Tools and Industrial Robots”, which promotes innovation to strengthen domestic manufacturing capabilities.

As a medium to high R&D-intensive sector, the machinery sector and its SMEs are heavily reliant on R&D investments. Accordingly, R&D support policies play an important role. For instance, Korea’s Smart Manufacturing Innovation Support Programme, under the Manufacturing Innovation and DX Acceleration Strategy, offers R&D funding and resources to help SMEs adopt advanced manufacturing technologies like smart factories, robotics, and process automation. A common feature across these policies is simplified access to R&D funding (e.g., through streamlined application processes). Within larger R&D projects, even those focused on developing SME-friendly solutions, SMEs often have limited involvement in resource-intensive development processes. To address this, some larger projects integrate technology transfer components for SMEs, such as Germany’s “ScaleMX” under Manufacturing-X, which includes support for networking, capacity-building and SME access to data-based solutions.

Bridging digital skills gaps is essential for SMEs navigating sectoral transitions, particularly in areas like automation, IoT, AI, and cybersecurity. In response, many OECD countries have introduced training initiatives, often implemented by local actors. A notable example is the longstanding U.S. Manufacturing Extension Partnership (MEP) (Box 2.12). Given the varying digital gaps between urban and rural areas and varying skills needs across regions, local actors play a crucial role in identifying training needs and ensuring effective programme design and implementation.

Towards a SME-responsive industrial policy framework for the manufacturing sector

Across OECD countries, the manufacturing sector is regaining strategic prominence, as evidenced by a wave of national industrial policy initiatives aimed at boosting global competitiveness, leveraging the low-carbon and digital transformations, and enhancing resilience to global disruptions. While these strategies

often target key sectors within manufacturing, direct and structured support for SMEs remains limited. Many industrial policies operate under the assumption that SMEs will benefit indirectly through trickle-down effects from broader sectoral growth. However, in today's rapidly evolving industrial landscape, marked by accelerated technological change, supply chain restructuring, and demands for resource-efficiency, such spillovers cannot be presumed to materialise automatically.

SMEs are not merely subcontractors in larger value chains – they are vital contributors to supply chain diversification, technological innovation, regional development, and economic inclusion. Empowering SMEs within industrial strategies is essential for building resilient and innovation-driven manufacturing ecosystems. Despite their strategic importance, SMEs often face structural disadvantages – limited access to finance, talent, and advanced technologies – that hinder their ability to fully engage in industrial transformation. To ensure SMEs are not left behind, industrial policy must evolve into a multi-layered framework that integrates SME-specific interventions with broader strategic goals.

Maximising the impact of industrial strategies requires deliberate synergies between general industrial policy and targeted SME support. This includes tailored funding mechanisms, simplified regulatory pathways, and access to collaborative innovation networks. Moreover, as governments pursue multiple objectives – such as enhancing supply chain resilience and in many countries, advancing the transition to a low-carbon economy, – potential trade-offs need to be carefully managed (Juhász, Lane and Rodrik, 2024^[4]). These complex dynamics demand well-designed, context-sensitive SME policies embedded within broader industrial strategies to ensure balanced and sustainable outcomes.

While the scope of this report is necessarily selective – focusing on selected manufacturing sub-sectors and countries – it indicates a growing recognition among governments of the need for industrial policies that more explicitly incorporate SMEs. Recent policy developments point to a gradual shift towards more targeted and better-integrated forms of SME support within broader industrial strategies. These emerging approaches are characterised by several common features, including:

Ecosystem approaches that foster structural linkages between SMEs and key players in local and global supply chains, including large firms and research organisations. These policies are designed to resolve co-ordination failures that risk sidelining SMEs by maintaining or strengthening their participation in the value chains. They can take various forms.

R&D networks

In sectors like automotive, policy strategies increasingly promote collaboration between OEMs and suppliers through R&D networks to drive innovation across the supply chain. However, SMEs often have limited ownership in large R&D projects due to size-related constraints. Therefore, embedding an SME-lens in government programmes implies including focus on niches where SMEs can unleash their innovation potential, as well as dedicated knowledge transfer components to ensure broad accessibility to a diverse group of SMEs.

Germany's Manufacturing-X, which funds industry-led R&D consortia, provides an illustrative case. The primary co-ordination failure addressed by the initiative is the lack of a unified data ecosystem in the manufacturing sector. This issue often forces SME suppliers to rely on proprietary digital systems developed by larger companies, creating dependency and limited transparency, which is needed for the sharing of data. To develop interoperable data ecosystems aligned with industry needs, consortia led by major industry companies carry out R&D projects co-financed by the government. An “ecosystem approach” is adopted by involving relevant actors of the ecosystem – including research institutions and SMEs – in the projects and by focusing R&D activities on the development of SME-friendly “plug-and-play” solutions, supported by targeted technology transfer measures to ensure effective deployment across the economy. The sub-initiative ScaleMX under Manufacturing-X initiatives further enhances support by offering capacity-building activities that enable SMEs to easily adopt these digital solutions. As the

Manufacturing-X initiative aims to standardise cross-border and cross-sector solutions, this provides a solid foundation for wide-ranging collaboration and innovation.

Regional clusters

Geographic clustering is a key ecosystem approach used to advance regional development, enhance industrial competitiveness, and strengthen supply chain autonomy. These clusters are typically supported through public subsidies and incentives that facilitate the co-location of research, manufacturing, design, and assembly activities. This model is particularly advantageous for SMEs, especially in high-tech sectors like semiconductors, where access to advanced infrastructure and collaboration with large firms is essential. To ensure that cluster development does not sideline SMEs, several countries have introduced targeted measures – such as dedicated funding streams, capacity-building initiatives, and platforms that foster collaboration between large firms and local SMEs. These efforts aim to strengthen SME capabilities and enable their integration into regional and global value chains.

An example of SME integration into cluster policies can be observed in Korea's Semiconductor Mega Cluster in Yongin, which aims to reinforce the domestic semiconductor ecosystem. The initiative includes the Semiconductor Ecosystem Fund and dedicates financial support for fabless SMEs, with the goal of increasing domestic self-sufficiency in key materials from 30% to 50% by 2030. Similarly, Japan's TSMC Kumamoto project reflects a strategic effort to bolster domestic semiconductor manufacturing by establishing a major TSMC production facility within Japan. The project is expected to generate significant benefits for regional SMEs, supported by financial instruments such as loans and guarantees under the Economic Security Promotion Act (2022). These examples illustrate how regional cluster policies, when designed with an SME lens, can serve as powerful tools for industrial development that actively engages SMEs.

Place-based skills development and networking support for SMEs: As megatrends, particularly digitalisation, reshape the manufacturing sector, the demand for new skills is rapidly evolving. SMEs are finding it increasingly difficult to keep pace, as reflected in the widening digital skills gap between large firms, which often dominate data ecosystems, and smaller enterprises that face mounting complexity. This challenge has a significant regional dimension, with varying skill needs driven by factors such as regional specialisations in the production of emerging technologies, as well as a pronounced digital skills gap between urban and rural areas. Thus, policies that aim to address skills gaps of manufacturing SMEs are often implemented by regional actors, including regional innovation agencies, transformation networks or technology and innovation hubs – even when coordinated at the national level. In skill-intensive manufacturing sectors where large firms dominate, regional networking support is equally vital. Facilitating collaboration and knowledge exchange between SMEs and larger enterprises helps bridge capability gaps, accelerates technology transfer, and fosters innovation ecosystems that actively include SMEs.

A notable example of place-based and network-oriented support for manufacturing SMEs is the U.S. Manufacturing Extension Partnership (MEP). Created in 1988, this public-private partnership operates 51 centres across the U.S., providing skills development (e.g., in adoption of advanced manufacturing technologies and cybersecurity) through advisory networks and SME-targeted training programmes on advanced manufacturing technologies, especially relevant to each region. Korea's Semiconductor Mega Cluster Strategy also offers another example, with networking support to connect SMEs and start-ups with larger semiconductor firms.

Simplified access to funding and advice tailored to diverse SME needs: Manufacturing SMEs face major financing barriers, particularly for undertaking strategic innovation, due to high upfront costs for technical infrastructure, training and restructuring of organisational processes. Tailored financial instruments can boost SME investment, but broad SME participation depends on low-cost access to expert advice and simplified funding processes, such as streamlined R&D funding application processes, and proactive outreach to increase awareness of available programmes.

For example, Japan's Mikata project offers individual consulting services, including free expert advice, to help automotive SME suppliers adapt their business model for the CASE era (Connected, Autonomous, Shared, Electric vehicles). Similarly, the France 2030 investment plan includes initiatives like the "Improvement and Transformation of Sectors" project, which funds SME participation in regional transformation projects through grants and repayable advances. Given the varying readiness levels among manufacturing SMEs, even within the same sector, targeted and differentiated support is crucial. In Germany, targeted initiatives typically provide an initial point of contact, guiding SMEs to relevant advice and funding opportunities (e.g., through consulting vouchers covering expert advice). For instance, "Transformationslotse Bayern", as a first point of contact, provides initial needs assessment, expert networks, training opportunities and funding guides tailored to each SME's transformation path.

Conclusion

Megatrends such as digitalisation, automation, transitions to low-carbon and energy-efficient economies, and geopolitical shocks are reshaping the industrial landscape and posing complex challenges for governments and firms. The pace and depth of SMEs' transitions towards more digital, low-carbon and resilient business models vary significantly across sectors and countries, underscoring the need for granular analysis which can underpin differentiated policy responses.

A persistent challenge is that industrial policy initiatives often prioritise large enterprises - particularly evident in recent reshoring and strategic autonomy efforts - while sidelining SMEs, despite their central role in supply chains and innovation ecosystems. Ensuring that SMEs have equitable access to essential resources such as finance, training, networks, and advisory services is a strategic necessity. Given their central position in production networks and their heightened exposure to policy shifts and market volatility, SME-responsive policies are essential to strengthening the resilience, competitiveness, and adaptability of manufacturing systems as a whole.

This report explores key trends, identifies priority policy areas, and highlights emerging practices for designing industrial strategies in the manufacturing sector that actively include SMEs. It underscores the value of adopting a balanced, multi-layered policy approach - one that thoughtfully navigates trade-offs and promotes alignment between overarching industrial objectives and targeted support for SMEs. Such an approach can contribute to more resilient and forward-looking industrial ecosystems.

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2 Sectoral analysis

This chapter provides an in-depth analysis of selected manufacturing sub-sectors (i.e., automotive, electronics and semiconductor, and machinery and equipment) that are being significantly reshaped by global megatrends such as digitalisation, automation, the transition to resource-efficient production models, and geopolitical and economic disruptions. Recognising the large diversity among manufacturing SMEs, the report focuses on these sub-sectors as illustrative examples of how such transformations are unfolding in practice. This targeted approach enables more nuanced insights on opportunities and challenges and supports the identification of tailored policy lessons.

Methodological note

The analysis focuses on three manufacturing sectors: automotive, electronics (semiconductor), and machinery. These were identified among 24 sub-sectors of the manufacturing industry (classified by the International Standard Industrial Classification of All Economic Activities (ISIC), Rev. 4, United Nations), based on criteria such as SME value-added contribution, employment proportion, and interconnectedness with other sectors and industries within the economy. Details regarding the industry selection and methodology are described in Box 2.1 below.

Box 2.1. Methodology for selecting sectors for analysis

The analysis focused on manufacturing sub-sectors where SMEs are both highly active and deeply embedded in broader economic and industrial systems. The selection followed a structured, multi-step process:

Identification of SME-dominant subsectors, using value-added and employment data

From the 24 manufacturing sub-sectors defined in ISIC Rev.4, eight SME-dominant sub-sectors were identified. These include automotive, machinery, electronics, fabricated metal, food, rubber and plastics, electrical equipment, and wearing apparel. SME contributions to value added in these sub-sectors range from 49% to 68%, and employment shares are similarly high, ranging from 50% to 65%.

Assessment of sectoral linkages and economic relevance using Input-Output Tables (IOTs)

IOTs were employed to trace the flows of inputs and outputs across these SME dominant sectors. This analysis highlights how SME-dominant subsectors interact with other parts of the economy and helps to estimate SME indirect contribution to national economy and the entire manufacturing industry. This method captures the systemic value created through supply chains, where SMEs serve as upstream suppliers to larger manufacturing firms.

Selection of sectors with both strong SME involvement and significant economic impact

Further refinement based on the size and strategic importance of sectors, along with alignment to national policy priority, led to the selection of **automotive, electronics (semiconductor), and machinery** as the focus sectors for the study. These three sectors stand out for their strong forward and backward linkages with other industries, high levels of SME participation, particularly as suppliers and intermediate goods producers for larger firms, and their significant contribution to total manufacturing output, reflecting the broader economic weight of SMEs through their integration in production chains.

Automotive Sector

Automotive sector, a cornerstone of global manufacturing with vast networks of interconnected industries

The automotive industry necessitates economies of scale, supported by a wide-ranging network of related industries, forming a pyramid-like structure for production and assembly (Kim, K.Y., 2022^[1]). An automotive manufacturer assembles numerous components, which in turn, require a variety of materials. This demand for materials is critical to the upstream industries such as steel, aluminium, rubber, glass, and plastics. The automotive sector is also closely linked with downstream industries, including maintenance services,

transportation, and finance, making it a crucial driver of economic activity across its value chain. In other words, the automotive industry relies on the interplay between related industries and concentrates in regional hubs within advanced manufacturing countries.

In Europe, the automotive industry directly and indirectly employs approximately 13.8 million workers, which accounts for 6.1% of the total employment within the European Union. 2.6 million people are engaged specifically in the manufacturing of motor vehicles, constituting 8.5% of all manufacturing employment across the EU (European Commission, 2024^[2]). In the United States, the automotive sector accounts for around 3.3% of national value added, with 1% stemming directly from manufacturing of motor vehicles and the remainder arising from activities of upstream suppliers and downstream distribution (Dechezleprêtre et al., 2023^[3]). This sector supports 9.6 million jobs, encompassing direct, indirect, and induced employment, equating to 4.9% of the total U.S. workforce (Alliance for Automotive Innovation, 2024^[4]). In Japan, the automotive industry represents approximately 2.9% of GDP and accounts for 13.9% of the manufacturing GDP (International Trade Administration, 2024^[5]).

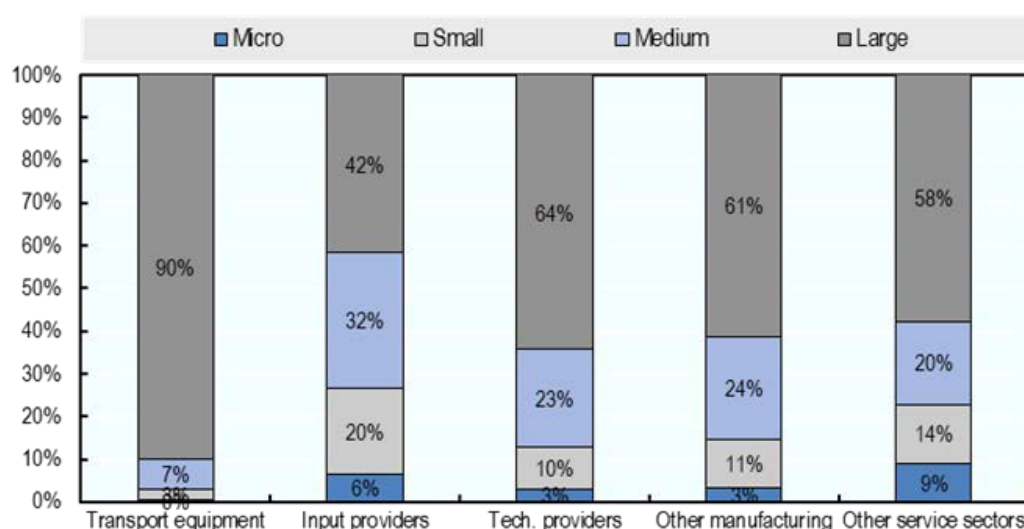
The complexity of the automotive industry's value chain is most evident in internal combustion engine vehicles, which consist of over 30 000 components. This complexity has resulted in the development of an advanced network of suppliers and manufacturers, which has subsequently evolved into a multi-tiered supply chain centred around carmakers. This structure not only underscores the logistical prowess of these manufacturers but also highlights their strategic management of an intricate web of supplier relationships as a pivotal organisational asset.

The core value chain starts with research and development, moving through procurement, assembly, marketing, sales, and culminating in after-sales service (as illustrated below in Figure 2.2A, left). Integral to this value chain are the material and component suppliers, which also have their own suppliers. The evolution of the automotive sector has ushered in a refined structure wherein Tier 1 suppliers – the linchpins of this ecosystem – aggregate detailed components from a broad network of Tier 2 and Tier 3 suppliers, many of which are SMEs. These SMEs contribute specialised parts and materials that are essential for Tier 1 suppliers' creation of modular assemblies for carmakers. This process not only underscores the importance of Tier 1 suppliers but also requires a close and collaborative relationship with carmakers, especially in the realms of innovation. It is commonplace for these Tier 1 entities to be closely knit with carmakers, either as subsidiaries or through strategic partnerships and equity swaps, further solidifying this intricate network. A notable exception within this framework is the production of engines by vehicle manufacturers themselves. Given the engine's critical role as the heart of the internal combustion vehicle, coupled with the high degree of technical sophistication required, carmakers opt for in-house production. This strategy ensures the safeguarding of proprietary knowledge and technological competencies, essential for maintaining competitive advantage. The engine represents a significant asset in terms of intellectual capital, characterised by tacit knowledge that extends beyond formal intellectual property, thus serving as a formidable barrier against potential new entrants into the market. This sophisticated orchestration of the automotive supply chain not only exemplifies the sector's logistical and strategic expertise but also reflects the dynamic interplay of collaboration and competitive differentiation that underpins the industry's ongoing evolution (Kim et al., 2022^[6]).

SME important role in the automotive industry's value chains

SMEs are well-integrated and play a significant role in the value chains of the automotive industry. Across OECD countries, micro firms and SMEs make up 98% of enterprises in sectors related to manufacturing of transport equipment, input and tech provision, and services. While large firms generate the majority of value added (67%), SMEs play an important role in different segments of the value chain, especially in the lower tiers (OECD, 2024^[7]). For example, as input providers, micro firms and SMEs generate 58% of the value added (Figure 2.1).

Figure 2.1. Distribution of value added in the automotive value chain by firm size (%) 2016-2018



Note: Country sample = France, Germany, Italy, Korea, Spain, Sweden, the United Kingdom. Size groups are based on the number of employees: Micro (1-9), Small (10-49), Medium (50-249), Large (250+).

Source: Dechezleprêtre, A., et al. (2023^[8]), "How the green and digital transitions are reshaping the automotive ecosystem", OECD Science, Technology and Industry Policy Papers, No. 144, OECD Publishing, Paris, <https://doi.org/10.1787/f1874cab-en>.

SMEs are largely present in different branches of the automotive value chain ranging from raw material, component and module providers (upstream) to retail, services and maintenance (downstream). Recent OECD research highlights the important role SMEs play in job creation within sectors closely tied to the automotive industry. This includes manufacture of rubber and plastics products, manufacture of basic metals, manufacture of fabricated metal products, as well as the wholesale and retail trade and repair of motor vehicles and motorcycles, where micro firms and SMEs account for 67% of total employment (Dechezleprêtre et al., 2023^[8]; OECD, 2024^[7]).

Transformative trends and the evolution of automotive value chains

Megatrends are shaping the automotive sector

The automotive industry is changing rapidly, driven by technological advances, regulatory mandates, market demands, and macroeconomic conditions. In recent years, many governments have introduced regulations and incentives to reduce greenhouse gas emissions in the transport sector, particularly by promoting the adoption of hybrid and electric vehicles in the place of internal combustion engine cars. At the same time, reflecting the advancement of information and communication technology, vehicles are transitioning from basic transportation tools to fully integrated, connected devices. Increasingly, drivers can receive real-time traffic data and leverage support from autonomous driving technologies, which significantly improves the overall driving experience. These automotive trends can be characterised by the acronym CASE, i.e. connectivity (Connected), autonomous driving (Autonomous), flexible usage (Shared), and electric drive systems (Electric)¹. These structural changes in the automotive industry have brought about transformations in the existing supply chain, which involves numerous SMEs.

For instance, the shift towards electromobility is leading to relocation of production networks², particularly impacting regions currently relying on manufacturing of traditional internal combustion engines. For example, in Germany, the automotive cluster in the state of Baden-Württemberg faces a predicted 7% drop of employment by 2030, depending on the scenario, with traditional powertrain-dependent sites facing

up to 56% of job losses (e-mobil BW, 2023^[9]). Small and medium-sized suppliers, in particular component producers for internal combustion engines, are especially vulnerable to these changes.

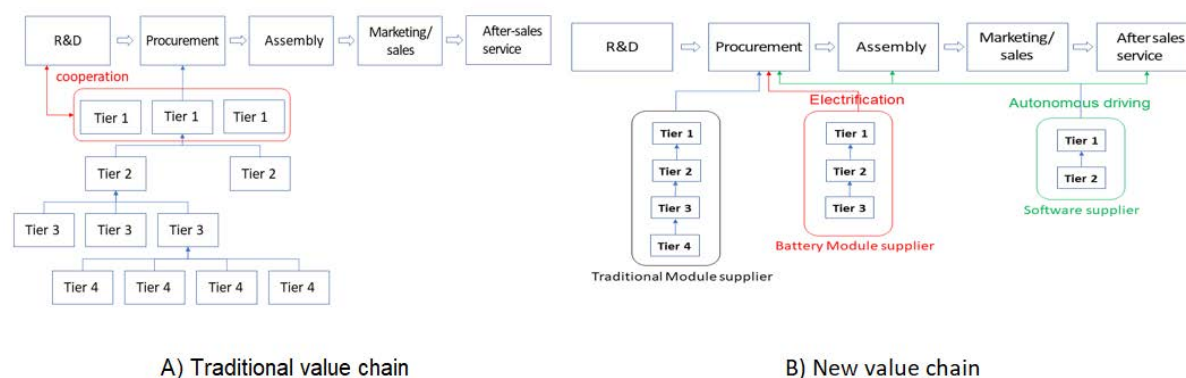
The ongoing process of digital transformation is also reshaping automobiles and their value chains. The growing integration of software and hardware components has increased vehicle functionalities and complexity, with digital technologies now accounting for over 50% of a vehicle's total value (Llopis-Albert, Rubio and Valero, 2021^[10]). As these technological advancements reshape the industry, the autonomous driving market is also expanding, with potential revenues projected to reach USD 300-400 billion by 2035 (McKinsey, 2023^[11]). This market growth provides many opportunities for companies, especially those involved in production of electronic interfaces, operating systems, and hardware components such as sensors and high-tech cameras.

On top of these structural changes, the automotive industry experienced two significant disruptions due to the COVID-19 pandemic, which highlighted supply chain vulnerabilities. In early 2020, during the first wave of the outbreak in the United States, the closure of automotive facilities restricted the supply of vehicles. Subsequently, in late 2020, a persistent shortage of semiconductor chips throughout the automotive supply chain obstructed production efforts aimed at meeting the rebounding consumer demand (Coffin et al., 2022^[12]). In Korea, factories halted due to a shortage of automotive wiring harness imports from China (Lee and Jin, 2020^[13]). These component procurement issues subsequently led major automotive companies to actively engage in global value chain (GVC) risk management. At the same time, COVID-19 negatively impacted the growth of the car-sharing business, as users preferred owning cars due to the risk of infection.

The evolution of automotive value chains

With the advent of electric and autonomous vehicles, the automotive landscape is undergoing a radical transformation. Traditional internal combustion engine components, including the engine, transmission, and associated parts, are being gradually phased out. Instead, batteries and electric motors have emerged as the new power generation systems, complemented by an array of sensors and software dedicated to autonomous driving. This paradigm shift is succinctly illustrated in Figure 2.2, which introduces the value chains for electrification, including batteries and e-powertrains, and for autonomous driving technologies. The electrification segment encompasses the production of motors, reduction gears, and various control devices that make up the e-powertrain, along with companies supplying raw materials and components necessary for battery manufacturing. The autonomous driving segment, on the other hand, comprises sensor manufacturers, such as those producing cameras, radars, and Light Detection and Ranging (LiDAR) systems, companies designing and manufacturing AI chips, and firms developing autonomous driving software. While these new value chains currently exist outside traditional vehicle manufacturers, it is conceivable that automakers may internalise these functions to some extent, further integrating these new technologies into their core operations (Box 2.2).

Figure 2.2. Transformation of value chain in the automotive industry



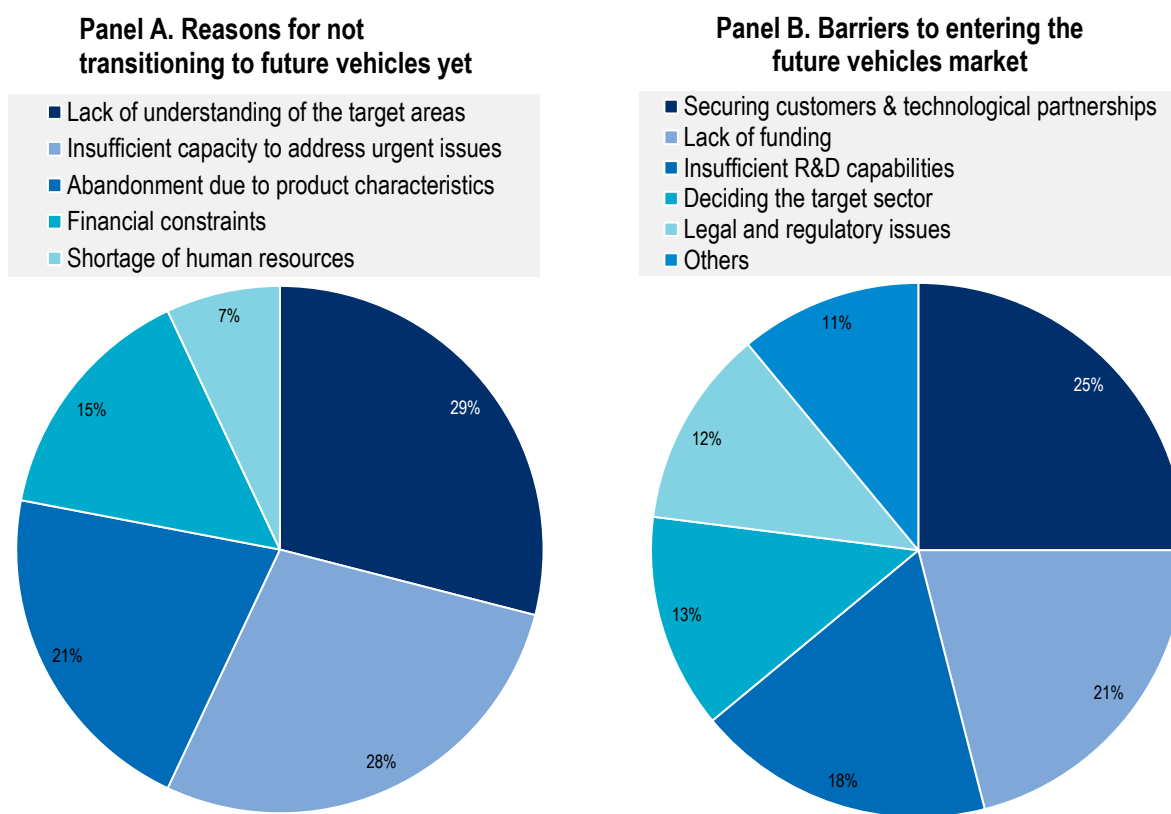
Source: (Kim et al., 2022^[6])

Implications for SMEs: challenges and opportunities for the transition to future vehicles

The restructuring of the value chain in the automotive industry has important implications for the components manufacturers and numerous SMEs in the supply chain. The transition from internal combustion engine to electric powertrains is causing job losses in automotive clusters, particularly affecting small and medium-sized suppliers that rely on internal combustion engine component production as their core business. This transition demands substantial investments in new technologies. As highlighted by a 2023 survey of 74 German automotive suppliers, the shift from internal combustion engine to alternative powertrain technologies requires significant financial resources within these businesses, while the share of profits from e-mobility products (10% of total profit) remain considerably smaller than the share of investments in e-mobility (28% of total investments) (see *country profile Germany*, Manufacturing SME readiness).

However, the extent to which this evolution impacts suppliers varies significantly depending on the product and the size of the company. According to a survey by the Korea Automobile and Mobility Association, a large number of suppliers, especially smaller ones, are not ready for the transition to future vehicles. This concerns 84% of small-sized enterprises, 58% of medium-sized enterprises and 24% of middle-market enterprises³ (Korea Automobile and Mobility Association, 2022^[14]). As illustrated in Figure 2.3, the reasons for not transitioning to future vehicles are largely related with a lack of knowledge about the target sector (29%) and the need to respond to current issues (28%), followed by financial (15%) and human resource (7%) constraints. The proportion of companies indicating that they are not transitioning due to their current products not aligning with future vehicle trends is also 21%. The barriers to entering the future vehicle market were identified in the following order: securing customer demand and technological partnerships (25%), lack of funding (21%), insufficient R&D capabilities (18%), and deciding the target sector (13%), and finally legal and regulatory issues (12%).

Figure 2.3. Transition to future vehicles in the automotive industry in Korea



Source: (Korea Automobile and Mobility Association, 2022^[14])

Although the majority of SMEs within the automotive industry recognise the ongoing structural changes, this recognition often does not lead to active and effective responses. Both upstream (e.g., component manufacturers) and downstream (e.g., service providers), SMEs are particularly impacted by shifts such as digitalisation and growing software integration, requiring them to adapt to the increasing complexity of automotive systems. However, many SMEs, especially those situated lower in the value chain, struggle to enhance their existing products due to limited capacity and resources, preventing them from taking proactive, future-oriented actions.

On the other hand, ongoing regulatory developments in the area of autonomous driving, coupled with significant public and private investments, create tangible opportunities for SMEs within the automotive value chain. For instance, the growing integration of software components presents new market entry opportunities for SMEs in the ICT-sector, particularly in fields like cybersecurity, testing, and digital image processing (OECD, 2024^[7]). This shift toward digital technologies is underscored by the fact that more than 20% of automotive startups are now primarily focused on ICT services and software development (EC, 2020^[15]).

At the same time, independent SMEs, including those in ICT services and software development, face strong competition from global software developers. Over recent years, large multinational ICT corporations have developed connected and autonomous vehicle systems (Financial Times, 2018^[16]). This growing competition is also pushing OEMs to heavily invest in R&D with the objective to increase control over the value chain through development of in-house software systems (OECD, 2024^[7]). To strategically enhance their expertise, data infrastructure, and service offerings, OEMs also increasingly collaborate with multinational ICT companies, including in areas beyond autonomous driving, such as the automation of

production processes. This shift is reflected in the recent emergence of new collaborative platforms such as the *Open Manufacturing Platform* (BMW and Microsoft) or the *Industrial cloud* (Volkswagen, Amazon Web Services and Siemens) (Box 2.2). SMEs in the automotive value chain, particularly those offering ICT services, software, and connectivity-related components, are increasingly dependent on OEM and Tier 1 strategies regarding collaboration and knowledge sharing. The extent to which they choose to engage with smaller suppliers will play a critical role in shaping opportunities for these SMEs.

Box 2.2. OEM strategies – Co-operations with major tech companies and suppliers to automate production processes

Open Manufacturing Platform (BMW and Microsoft, 2019)

The Open Manufacturing Platform, founded by German car manufacturer BMW and Microsoft in 2019, represents an example of co-operation between an OEM and a major tech player. The initiative aims to develop a standardised production platform using open-source software in order to share smart factory solutions boosting industrial IoT developments (Microsoft, 2019^[17]). The platform aims to achieve this by facilitating seamless sharing of knowledge, data, and emerging technologies, fostering innovation across sectors – including manufacturers and supplier from outside the automotive sector.

Industrial cloud (Volkswagen, Amazon Web Services and Siemens, 2020)

To boost factory automation and accelerate the supply of smart factory solutions, Volkswagen collaborated with Amazon Web Services and Siemens, creating an industrial cloud open for companies working in mechanical engineering. This enabled all partner companies to connect to Volkswagen sites on the cloud and contribute with their own software applications to optimise production (Volkswagen, 2021^[18]).

Role of government policies and regulations

Regulations

In many countries, the transition to vehicle electrification is being driven by national regulations and commitments aimed at reducing greenhouse gas emissions. Globally, the EU has the most far-reaching exhaust emissions regulations, with its Euro X standards⁴ serving as a benchmark for other countries including China, and Korea. China's vehicle emission regulations have largely aligned with those of the EU, with the implementation dates lagging behind the equivalent EU standard by a period of 5-10 years. However, China has integrated elements from both European and past U.S. regulatory frameworks while also establishing its own unique requirements since the state 6 standard in 2020 (He and Yang, 2017^[19]). Korea adopted the ultra-low emission vehicle standard for gasoline, based on California's ultra-low emission vehicle standards, and the Euro X for diesel (Mecar, 2024^[20]).

European climate law mandated reducing emissions by at least 55% by 2030 and proposed the fit for 55 package⁵, a detailed execution regulation. According to the roadmap, traditional internal combustion engine cars will be phased out. However, the ban on internal combustion engine cars exempts vehicles that run exclusively on e-fuels, synthetic fuels made by combining hydrogen and carbon dioxide captured from the atmosphere (European Council, 2023^[21]).

Globally, many countries have established targets for zero-emission vehicles and plans to phase out internal combustion engine vehicles. Some countries set a target of 2035, while others have established more aspirational goals, aiming at 2050.

Subsidies and tax rebates for Electric Vehicles

In many countries, the gradual intensification of fuel economy and greenhouse gas emission standards from vehicle exhausts has increased the sales of electric vehicles (EVs). Specifically, CO₂ emissions regulations in the European Union have led to a significant spike in sales of electric cars, with approximately 2.1 million electric cars sold in 2020 (IEA, 2021^[22]). Globally, nearly 14 million new electric cars were sold in 2023, 95% of which were traded in China, Europe, and the U.S. In 2024, one year later, global car sales increased by 3.5 million reaching over 17 million new EVs (IEA, 2025^[23]). Notably, the trend endured even amid a decline in overall car sales in Germany from 2022 to 2023, mainly caused by the phaseout of purchase subsidies (IEA, 2024^[24]).

Many countries have introduced subsidies and tax rebates for buying and registering EVs to encourage take-up and spur innovations in the industry, in order to make electric vehicles more price-competitive compared to traditional internal combustion engine vehicles, as well as spur private investment in electric vehicle infrastructure, such as charging points. Such policies were introduced in Norway in the 1990s, the United States in 2008 and China in 2014, providing incentives for the growth of the electric vehicle market (IEA, 2021^[22]). Some countries have since ended or planned to phase out EV subsidies considering the market share of EVs, the budget constraints and a narrowing price gap with internal combustion engine cars (IEA, 2025^[25]). For example, Norway, where all-electric vehicles made up 80% of passenger vehicle sales in 2022 (Jaeger, 2023^[26]), no longer has tax benefits nor purchase incentives. As of 2024, among the 27 EU member states, fifteen still provided purchase subsidies for ZEV commercial vehicles (vans, trucks, and buses), and twenty offered purchase subsidies for passenger EVs (BEV, PHEV, HEV, FCEV etc) (ACEA, 2024b^[27]). China increased purchase subsidies during the COVID-19 pandemic period but has completely abolished the subsidy payments for electric vehicle purchases (Table 2.1). In the case of the U.S., there is no federal direct purchase subsidy currently in place. Tax credits up to USD 7 500 depending on household incomes were offered from January 2023 through September 2025 – these were then discontinued. California had offered rebates up to USD 7 500 in terms of the Clean Vehicle Rebate Project but stopped rebates in 2023. In Korea, the subsidy limit for medium and large electric passenger vehicles was reduced by KRW 1 million, equivalent to around USD 700 (from KRW 6 to 5 million, USD 4 200 to 3 500). A new upper limit of KRW 4 million (around USD 2 800) was established for subsidies for small and light electric passenger vehicles, and the subsidy for micro electric passenger vehicles was reduced from KRW 4 million to 3.5 million (around USD 4 200 to 2 500). Contrary to the trend of reducing or abolishing subsidies, Japan is raising the subsidy limits to expand the electric vehicle market, for example from JPY 400 000 (around USD 2 700) in 2020, to JPY 650 000 (around USD 4 300) in 2023 and JPY 850 000 (around USD 5 600) in 2024.

Table 2.1. EV subsidy and tax exemption in China

	2018	2019	2020	2021	2022	2023
Purchase subsidy (USD Billions)	4.3	3.3	3.5	7.4	9.2	0
Sales tax exemption (USD Billions)	7.7	6.4	6.6	16.4	30.3	39.6
Subsidy per vehicle (USD)	13 860	12 311	12 294	8 538	6 656	4 764

Source: (Center for Strategic & International Studies, 2024^[28])

The effectiveness of electric vehicle subsidies and tax incentives has varied across countries, as measured by the additionality index, that is, the share of EV purchases induced by the subsidy policy (Sheldon and

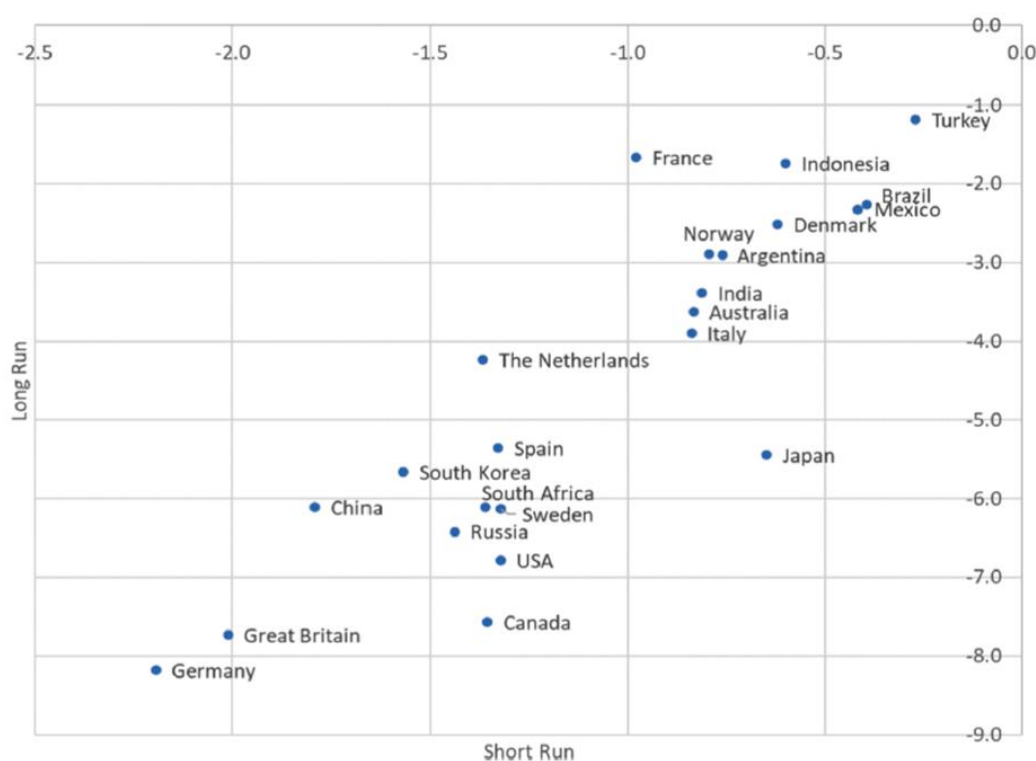
Dua, 2024^[29]). The measured index for 2019 was lowest in Japan and highest in Korea. According to Sheldon and Dua (2024^[29]), the large difference can be explained by the price sensitivity of consumers and the amount of subsidies. The cost per additional EV was highest in Japan while the cost per additional EV was lowest in Germany for the same reasons (Table 2.2).

Table 2.2. The cost for additional EV in 2019

	Mean Direct Incentive	Cost/EV	Additionality
Canada	3 791	24 512	19
China	1 942	17 741	14
France	3 919	32 589	17
Germany	3 161	14 857	24
India	678	37 135	2
Italy	2 437	34 759	9
Japan	1 657	45 626	1
Korea	5 497	22 108	33
Spain	154	23 136	4
Sweden	3 792	23 982	16
US	7 178	24 273	26
UK	1 351	16 354	12

Source: (Sheldon and Dua, 2024^[29])

Figure 2.4. Estimated Price Elasticity of Demand of EVs (2010-2019)

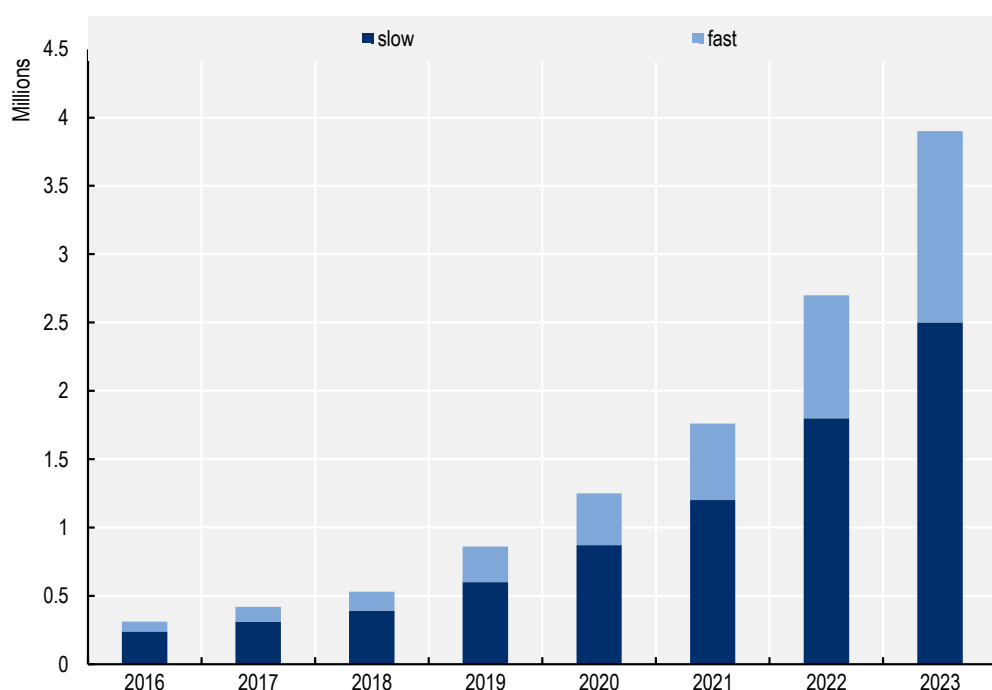


Source: (Sheldon and Dua, 2024^[29])

Support for Electric Vehicle Charging Infrastructure

A critical factor in the adoption and spread of EVs is the availability of sufficient charging stations. While home charging stations currently satisfy the majority of EV charging needs, the expansion of publicly accessible charging infrastructure is key for convenience and accessibility to be comparable to traditional fuel stations. This is particularly the case in densely populated urban areas, where the availability of home charging facilities is often limited or inconveniently located, as well as at major rest stops on highways frequented by long-distance travellers. Public fast chargers are especially relevant in these settings. Globally, the number of charging stations has increased significantly in recent years, with the growth rate of fast-charging stations being particularly rapid (Figure 2.5).

Figure 2.5. Number of EV charging points, globally, 2016-2023



Source: (IEA, 2024^[30])

As of 2023, China recorded the highest number of public charging facilities, accounting for 69% of the total number of charging points, with its share of slow chargers at 60% and fast chargers at 86% (IEA, 2024^[30]). Relative to population size, this represents 1.9 charging stations per thousand inhabitants, compared to approximately 1.3 per thousand inhabitants in the EU27. This outcome is linked to China's substantial investments and complementary policies aimed at fostering the growth of its EV charger industry (Table 2.3).

Table 2.3. Policies targeting on charging infrastructure for new energy vehicles in China

Policy document	Key point	Issued date
Guiding Opinions on Further Constructing a High-Quality Charging Infrastructure System	Goals by 2030 include establishing a comprehensive charging network that covers urban, highway, and rural areas, improving standardisation, regulation, and market supervision systems, and achieving global leadership in charging technologies.	June 2023
Accelerating the Development of Charging Infrastructure to Better Support the	Supporting local governments in developing county-level public charging network plans. Prioritising the installation of public charging facilities in commercial buildings,	May 2023

Deployment of New Energy Vehicles in Rural Areas and Rural Revitalization	transportation hubs, and service areas along highways.	
Guiding Opinions on Promoting the Development of Energy Electronics Industry	Enhancing the application level of energy electronic products in emerging facilities, such as 5G base stations and new energy vehicle charging stations.	January 2023
Implementation Plan for Expanding Domestic Demand in the 14th Five-Year Plan	Strengthening the construction of supporting facilities such as parking lots, charging stations, battery swapping stations, and hydrogen refuelling stations.	December 2022
Plan for Modern Energy System in the 14th Five-Year Plan	Optimising the layout of charging infrastructure and comprehensively promoting the coordinated development of vehicles and charging stations. Conducting pilot demonstrations of innovative charging and battery swapping stations that integrate solar power generation, energy storage, and charging.	March 2022
Implementation Plan for Enhancing the Service Capability of Charging Infrastructure	Coordinating the construction and retrofitting of charging stations in residential communities.	May 2021
Development Plan for the New Energy Vehicle Industry (2021-2035)	Promoting the scientific layout and accelerating construction of charging stations and providing financial support for the construction of public charging stations.	November 2020

Source: (Fu, 2023^[31])

In May 2024, a subsidy programme to develop the charging infrastructure was launched in the United States. The initiative, supported by the Bipartisan Infrastructure Law, included investments in EV charging through the USD 2.5 billion Charging and Fuelling Infrastructure (CFI) Discretionary Grant Program and funds from the National Electric Vehicle Infrastructure (NEVI) (Joint Office of Energy and Transportation, 2024^[32]). The last funding round of the CFI programme was closed in November 2024, and, in early 2025, new spending obligations under NEVI were suspended pending revised federal guidance.

Technological progress and evolving regulations in autonomous driving

The commercial development of autonomous driving is advancing rapidly. Societal demands are fostering the growth and development of autonomous driving across a wide range of applications. In recent years, the demand for mobility services has shifted from car ownership to transportation tools. “Robotaxi” provides an example in this regard, even if immature technological readiness, lack of relevant systems, and still higher costs compared to existing solutions act as obstacles to commercialisation. However, the technological breakthrough in artificial intelligence and technological progress in the area of high-speed data transfer networks leads to continuous and fast enhancement of automated driving (Box 2.3).

Box 2.3. Advancements in autonomous driving testing

The advancement of road testing also facilitates the commercialisation of autonomous driving. The Society of Automotive Engineers (SAE) in the U.S. defines six levels of vehicle automation ranging from Level 0 to Level 5 (Table 2.4), starting at Level 3, where the driver is not in control when the automated system is active but must take over when the system requests it. In California, as of 2024, 38 companies hold permits for testing autonomous vehicles with a safety driver, six for driverless testing, and three for deployment (California DMV, 2024^[33]). Test vehicles travelled over 9 million miles on Californian roads from December 2022 to November 2023, with 3.3 million miles driverless. The National Highway Traffic Safety Administration (NHTSA) updated its autonomous vehicle crash reporting system for better accuracy. In China, 38 regions have issued regulations for intelligent vehicle testing, opening 5 200 km of test roads (China Academy of Information and Communication Research, 2022^[34]).

Table 2.4. SAE levels of driving automation

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Definition	No driving automation	Driver assistance	Partial driving automation	Conditional driving automation	High driving automation	Full driving automation
Driver's role	A driver is driving whenever driver support features are engaged, even feet are off the pedals and driver is not steering.			A driver is not driving when automated driving features are engaged – even if the driver is seated in the driver's seat.		
	A driver must constantly supervise support features; driver must steer, brake or accelerate as needed to maintain safety.		When automated driving feature requests it, a driver must drive.		The automated driving features will not require a driver to take over driving.	
Driver support features	Limited to providing warnings and momentary assistance.		Providing steering or brake/acceleration support to the driver.	Providing steering or brake/acceleration support to the driver.	Driving the vehicle under limited conditions and not operating, unless all required conditions are met.	Driving the vehicle under all conditions.
Example Features	Automatic emergency braking, blind spot warning, lane departure warning.	Lane centering or adaptive cruise control.	Lane centering and adaptive cruise control at the same time.	Traffic jam chauffeur.	Local driverless taxi, pedals/steering may/may not be installed.	Same as level 4, driving everywhere in all conditions.

Source: (SAE International, 2021^[35])

Autonomous driving is approaching large-scale deployment even if the regulatory framework and protection systems remain underdeveloped, with road management regulations, accident liability, and insurance policies still lacking maturity. As a result, major automobile-producing countries are working to establish relevant policies and refine their legal and regulatory systems. In 2021, the U.S. Department of Transportation announced the Automated Vehicles Comprehensive Plan, identifying short-term needs and directions for long-term change in the autonomous driving system (Table 2.5). The “New Automated Vehicle Framework”, announced in April 2025 emphasises both safety and the reduction of regulatory constraints. Among its measures, it proposes expanding the Automated Vehicle Exemption Program (AVEP) to include U.S. manufacturers, allowing access to faster exemption procedures for testing and operating non-compliant imported vehicles on U.S. roads (U.S. DOT, 2025^[36]).

Table 2.5. Automated Vehicle Comprehensive Plan of U.S. DoT (2021)

Vision	Prioritise Safety While Preparing for the Future of Transportation				
Goals	Promote Collaboration and Transparency	Modernise the Regulatory Environment			Prepare the Transportation System
		Streamline Paths to Deployment	Update Existing Regulations to Remove Unnecessary Barriers	Conduct Appropriate Safety Oversight of ADS	
Objectives	- Engage with stakeholders to monitor for emerging trends, issues, and needs - Provide guidance to industry to encourage transparency and adoption of best practices	- Issue exemptions and waivers consistent with applicable authorities - Streamline administrative processes for seeking exemptions and waivers	- Conduct rulemaking and research to adapt existing FMVSS to remove unintended and unnecessary barriers to the introduction of novel vehicle designs and features enabled by ADS - Adapt existing FMCSRs to	- Explore new approaches to safety assurance and investigate innovative models and tools to evaluate the safety of ADS technologies	- Conduct targeted technical research - Provide funding for ADS-focused demonstrations, pilots, and deployments - Update

	- Facilitate information sharing		remove unnecessary barriers to the operation of ADS-equipped commercial motor vehicles in interstate commerce		infrastructure standards to reflect ADS technologies
Actions	Stakeholder Engagement, Research, Guidance Documents, Rulemakings				

Source: (U.S. Department of Transportation, 2021^[37])

In China, the regulatory framework for autonomous driving substantially evolved in recent years. In 2021, the proposed amendments to the *Road Traffic Safety Law* addressed legal aspects like traffic violations, liability, and accident compensation for autonomous vehicles. Autonomous driving road testing was also expanded, with the issuance of the *Interim Regulations on the Management of Intelligent Connected Vehicle Road Testing and Demonstration Applications (Trial)*, allowing the transport of people and goods on specific routes. The government has also set technical guidelines and entry requirements for manufacturers, focusing on safety standards for Level 3 and Level 4 vehicles. Additionally, the central government established standards to guide and promote the high-quality development of autonomous driving.

In Germany, the *Road Traffic Act (StVG)* was amended in 2017 and 2021 to grant general road operation permissions for autonomous vehicles, accompanied by updates to the *Compulsory Insurance for Vehicle Owners Act (PfIVG)*. In 2022, Germany introduced the *Autonomous Vehicles Approval and Operation Ordinance (AFGBV)*, underscoring its position at the forefront of Level 4 autonomous driving legislation. To guide these efforts, Germany established an *Autonomous Driving Ethics Commission* in 2017, to ensure that societal concerns and ethical considerations are addressed alongside technological advancements.

Novel opportunities for innovative start-ups and SMEs in growing market for autonomous driving

The autonomous driving market is a newly emerging market, where fierce competition is unfolding between big tech companies entering the automotive industry and established car manufacturers to seize market dominance. Major companies employ various strategies such as acquiring startups, establishing subsidiaries, and promoting co-operative alliances to secure competitive advantage as shown in Table 2.6. Incumbent companies are acquiring startups or creating strategic partnerships and subsidiaries to fill their insufficient software capabilities compared to ICT companies. Entrant car manufacturers are internalising autonomous driving technologies based on their own hardware and software capabilities, while acquiring startups in key technological areas to further enhance their development. Big tech companies are focusing on mobility services, relying on their strong software capabilities. AI/OS/Chip makers are collaborating with carmakers to provide autonomous driving platforms.

Table 2.6. Major Investments and Collaborations of Autonomous Driving Companies

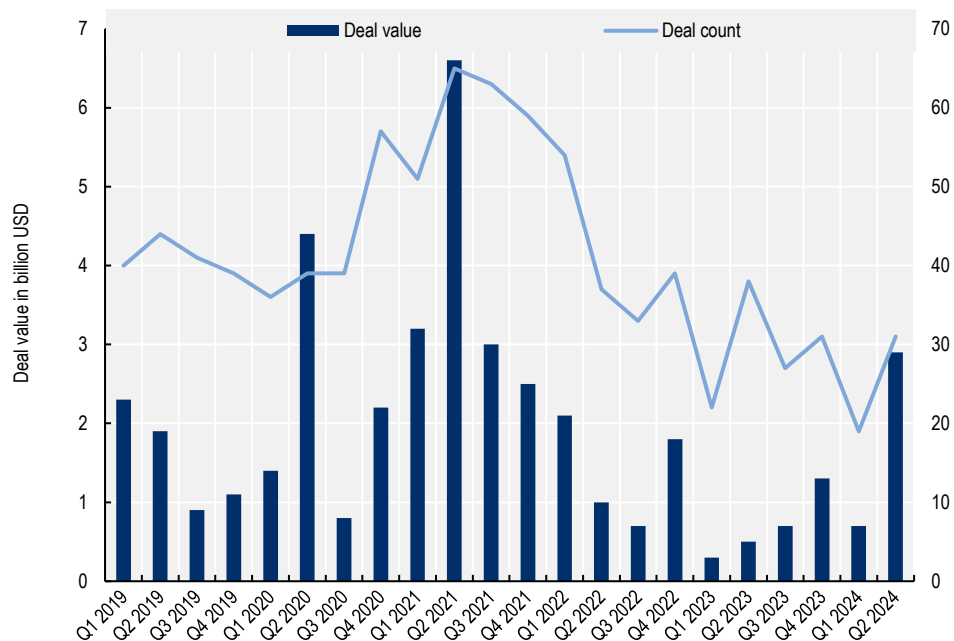
Category	Firm	Key example	Note
Incumbent	Ford, Volkswagen	Established Joint venture Argo AI in 2016	Disbandment in 2022
	Volvo	Collaborated with LiDAR startup Luminar in 2018	Delivering production LiDAR sensor in 2024
	GM	Acquired autonomous driving SW startup Cruise in 2016	Additional investment USD 850 million in 2024
	Hyundai Motor Group	Established Joint venture Motional with Aptiv in 2020	
Entrant	Tesla	Acquired autonomous driving SW startup DeepScale in 2019	
	NIO	Invested in LiDAR startup Innovusion in 2021	Innovusion rebrands as Seyond in 2023
	XPeng	Invested in LiDAR startup Zvision in 2022	

Big Tech	Alphabet	Founded Waymo as a subsidiary in 2016	
	Baidu	Invested in Velodyne Lidar in 2016	Three-year sales agreement in 2020
	Amazon	Acquired Zoox as subsidiary in 2020	
AI/OS/Chip	Nvidia	Acquired DeepMap in 2021	
	Intel	Acquired ADAS company Mobileye in 2017	
	Qualcomm	Acquired ADAS company Arriver in 2022	

Source: (Park, 2022^[38])

Regardless of who the investors are, the competition among these end-user companies presents a significant opportunity for startups. Investment in autonomous driving startups rebounded in 2024, after a deep slump in 2022. In the second quarter of 2024, autonomous driving startups attracted USD 2.9 billion in funding (Figure 2.6), the largest investment within the sector, which includes innovations in both passenger and goods transportation (Manske, 2024^[39]).

Figure 2.6. VC deal activity in autonomous driving sector, 2019-2024



Source: (Manske, 2024^[39]) based on PitchBook data.

Interestingly, corporate venture capital holds a significant share in investments in the autonomous sector (Table 2.7). This reflects the strategic approach of large corporations as they adapt to the structural changes in the automotive industry.

Table 2.7. Top VC investors in autonomous driving sector since 2014

VC	Type	Deal count
Toyota Ventures	Corporate Venture Capital	27
Intel Capital	Corporate Venture Capital	25
Bosch Ventures	Corporate Venture Capital	21

Trucks Venture Capital	Venture Capital	21
IDG Capital	Venture Capital	21
New Enterprise Associates	Venture Capital	21
Lux Capital	Venture Capital	20
Maniv Mobility	Venture Capital	18
BMW iVentures	Venture Capital	18
Alumni Ventures	Venture Capital	18
Samsung Catalyst Fund	Corporate Venture Capital	18
HongShan	Venture Capital	18

Source: (Manske, 2024^[39])

Major automobile-producing countries are implementing funding policies to support the development of autonomous vehicle technology. In the U.S., the Department of Transportation provided over USD 148 million in funding for over 83 projects in 2022 and 2023 through the strengthening mobility and revolutionising transportation grant programme (SMART Grants Program) (United States Department of Transportation, 2025^[40]). The programme runs from 2022-2026 with USD 100 million appropriated annually. In the EU, the autonomous driving is related with the Destination-Safe, Resilient Transport and Smart Mobility services for passengers and goods in the cluster 5-Climate, Energy and Mobility under the Horizon Europe framework (European Commission, n.d.^[41]). Especially, the Connected, Collaborative, and Autonomous Mobility Partnership (CCAM), coordinated by the European Commission in collaboration with private and public mobility sector stakeholders, serves as a key framework for co-operation within Horizon Europe. Its main aim is to create a mobility system that is more user-focused, while also addressing challenges such as accident prevention, the low-carbon transition, and traffic management. Additionally, the partnership emphasises improving understanding and acceptance of CCAM technologies across the European Union's public and institutional sectors.

In the UK, the government provides funding up to GBP 150 million for Connected and Automated Mobility (CAM) as a subpart of the Advanced Manufacturing Plan (United Kingdom government, 2023^[42]). The UK Government's funding for CAM is matched by industry contributions, enabling the Centre for Connected and Autonomous Vehicles (CCAV) to strengthen the UK's leadership in the development, deployment, and manufacturing of autonomous technologies and services. CCAV aims to establish an early commercial market and secure a competitive advantage in self-driving vehicle deployment. Since 2015, the organisation has facilitated approximately GBP 600 million in joint investment with industry across more than 100 projects nationwide.

In Germany, the Federal Ministry for Economic Affairs and Energy (BMWE) promotes innovation and competitiveness within the automotive industry. Since 2015, EUR 1.15 billion in project funding and EUR 629 million in grants have been provided to 80 collaborative projects with 719 sub-projects in autonomous driving under the funding programme "The DNA of sustainable mobility" (DNS der zukunftsfähigen Mobilität; formerly known as "New vehicle and system technologies") (BMWE, 2026^[43]). The programme's primary objective is to strengthen the innovative capacity and future viability of the German automotive and vehicle industry – paying particular attention to supporting SMEs. Priorities include AI-driven development, validating autonomous functions, and creating data ecosystems and reference architectures to advance autonomous mobility solutions. Overall, the numerous funding and collaboration opportunities for advancements in the field of autonomous vehicle technology offer innovative start-ups and SMEs in the sector with valuable support. By innovating in areas like AI and cybersecurity, SMEs can gain a competitive edge, and potentially expand operations.

SME-targeted policy support for the automotive value chain

Across the OECD, in particular in countries with strong automotive industries, policy support measures are in place to boost SME competitiveness and integration into value chains. In the fields of autonomous driving, access to data ecosystems and production of future vehicles targeted policy support includes funding for collaborative R&D projects, preferential interest loans and grants for investment projects as well as targeted skills and networking programmes. Despite extensive support measures, their impact on most SMEs remains unclear, as often the primary beneficiaries are innovative SMEs with more resources, allowing them to invest even with uncertain returns. For example, a recent survey of German automotive suppliers shows relatively high R&D expenditures for e-mobility (Oliver Wyman, 2023^[44]) – an area that demands significant financial and human resources, which smaller firms often cannot afford at the same scale as larger companies.

Maximising SME participation in innovation is essential for fostering competitive advantages within the automotive industry. As highlighted by recent OECD research on policies targeting the automotive value chain, automotive sectoral strategies, in particular across EU countries, mainly promote an “ecosystem approach” involving OEMs and suppliers in R&D networks (OECD, 2024^[7]). This ecosystem approach is evident in the policy measures of the countries analysed in this report. Notable examples include measures under France’s 2030 five-year investment plan (Box 3.3) and Germany’s Catena-X project (Box 3.6) which support R&D with a focus on SME integration and networking activities. The Catena-X project exemplifies how funding support for collaborative R&D initiatives can foster the creation of “SME-ready” standardised data solutions, enhancing SME integration within the automotive value chain. This aspect of collaboration is crucial, as OEMs and larger companies increasingly control data infrastructures in the supply chain.

Additionally, the analysis highlights that, beyond collaboration, R&D programmes targeting SME participation in cutting-edge projects (*see country profile Germany: “SME-innovative”*) must ensure that support is easily accessible. For example, this can be achieved through dedicated advisory services, simplified entry requirements and timely funding approval.

As outlined in this chapter, SMEs face significant financial challenges when attempting to adopt costly new technologies necessary for future vehicle parts production. Targeted policy programmes, some with broad sectoral focus but open to SMEs and others specifically tailored for them, support innovation in the development of future vehicles. Examples include capital investment subsidies and support for consulting services under the *Mikata project* in Japan (Box 3.15), calls for *investment projects to produce vehicles of tomorrow in France* (Box 3.3) and investment grants to modernise vehicle supplier’s production facilities as part of the *2020 economic stimulus package* in Germany. Financial support is crucial for enabling SMEs with limited resources to innovate, but, as illustrated by the country policy cases included in this report, it is as important to combine funding opportunities with expert guidance to effectively address the unique challenges faced by SMEs.

Finally, the transition to electric and autonomous vehicle production requires a workforce with specialised skills, such as expertise in battery technology or software development for vehicle automation. Some governments, in partnership with educational institutions and industry leaders, have established knowledge-sharing, training and networking programmes to support SMEs in upskilling their workforce, ensuring they can meet the technical demands of this evolving industry and remain competitive. Notable examples include the “*Compétences et Métiers d’Avenir*” in France (Box 3.3) with a focus on reskilling workers for digital and ecological roles for future vehicle production. Other examples are state policy programmes in Germany, which specifically target SMEs in the automotive value chain (*see State policy programmes offer targeted support for manufacturing SME transformation*). These programmes add value by disseminating knowledge through seminars, offering technical advice, and helping SMEs navigate funding opportunities. They also foster networking by connecting SMEs with regional transformation networks, thereby, complementing national policy programmes.

Electronics Sector (Semiconductor)

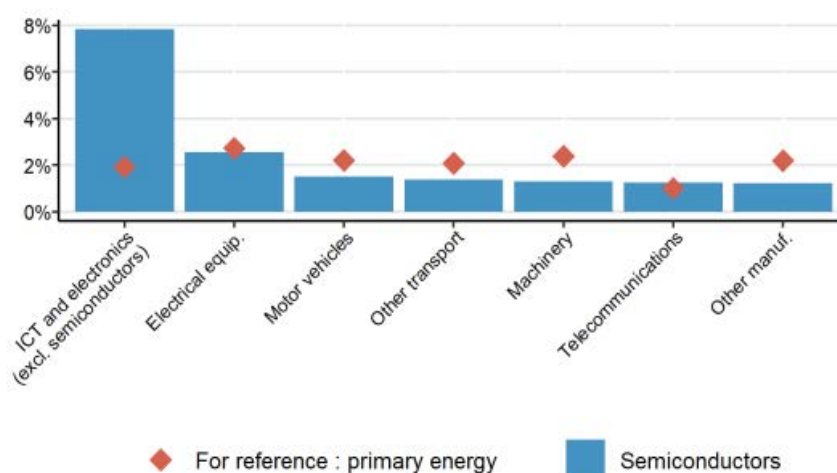
Electronics sector, driver of technological progress and economic growth

The electronics sector stands out for its rapid technological advancements and continuous innovation, serving as a critical driver of economic growth and technological progress in many OECD countries (OECD, 2024^[45]). The sector encompasses a wide range of products that are integral to various industries and consumer markets. Among its key components, semiconductors – often referred to as the ‘brains’ of modern electronics – stand out as the foundation of a wide array of devices, from smartphones and computer to critical infrastructure systems and advanced medical technologies (Box 2.4). These chips form the building blocks of electronic circuits for devices for everyday consumer gadgets to a range of downstream industries, including information and communications technology (ICT), electrical equipment, and motor vehicles, accounting for a sizeable share of value added in final demand, making semiconductors often referred to as ‘the new oil’ (Figure 2.7).

In response to transformative changes in the industry landscape, in recent years many countries have developed and implemented new industrial policies that target this sector. Given the pivotal role of semiconductors in the electronics sector and the growing importance in government strategies, the following analysis will focus on the semiconductor industry and the far-reaching implications of its ongoing transformation.

Figure 2.7. Share of semiconductor value added in final demand

Share of semiconductor value added as a percentage of final demand across sectors



Note: The sample is restricted to the leading purchasing economies: Brazil, Canada, China, France, Germany, Hong Kong (China), Ireland, Italy, Japan, Korea, Malaysia, Mexico, the Netherlands, the Philippines, Singapore, Switzerland, Chinese Taipei, Thailand, the United Kingdom, the United States. Primary energy includes coal, oil and gas.

Source: OECD semiconductor-augmented ICIO tables

Box 2.4. Understanding semiconductors: Logic, Memory, and DAO

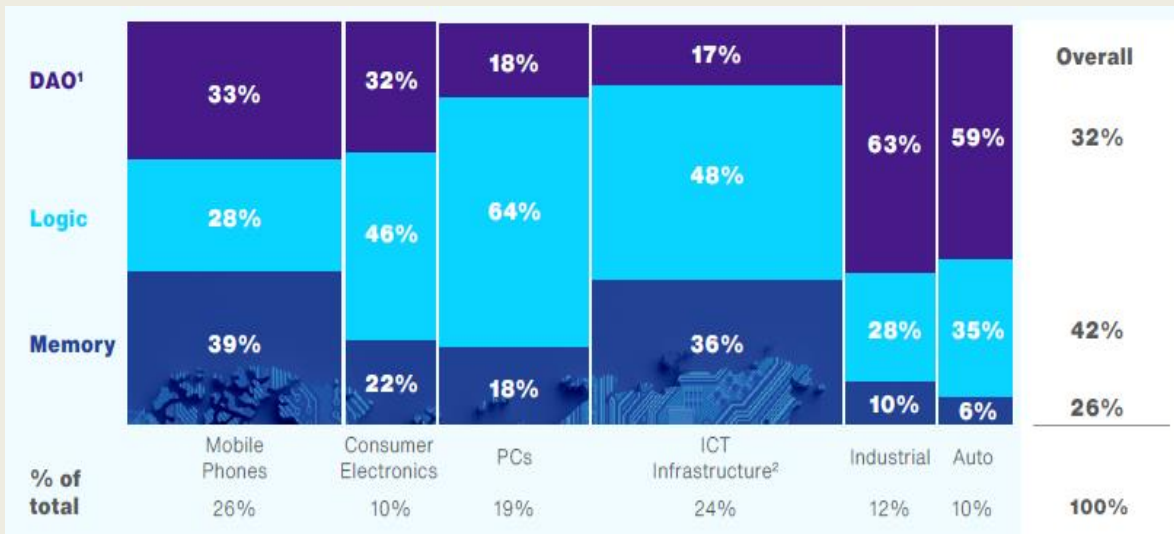
Semiconductors are small electronic devices made up of billions of components that can process, store, detect, and transmit data or signals. There are various types of semiconductor chips, including logic, memory, discrete, analogue, optoelectronics, and sensors, each performing different functions and requiring specialised design and manufacturing processes.

Memory semiconductors are designed to store data and instructions. They come in two main types: volatile (DRAM) and non-volatile (ROM). Memory chips are critical for tasks such as storing programmes, operating systems, and files in devices ranging from smartphones to supercomputers. Major producers in this group are Samsung (Korea), SK Hynix (Korea) and Micron (US).

Logic semiconductors are responsible for processing functions in electronic devices, such as executing instructions from software to perform tasks. These include microprocessors (CPUs) and graphics processing units (GPUs), which are responsible for decision-making processes within devices, such as calculating, processing data, and controlling other components. Leading producers are NVIDIA (US), Advanced Micro Devices (AMD) (US), TSMC (Chinese Taipei).

DAO (Discrete, Analog, and Optoelectronics) are critical for various electronic functions like switching, amplifying, and rectifying electrical signals, or converting real world information like sound or light into digital data and electronic signals. There are various companies in this category including SMEs in many countries like Germany, Italy, Japan, Switzerland, and the US.

Infographic 2.1. Global semiconductor sales by application market, 2019 (%)



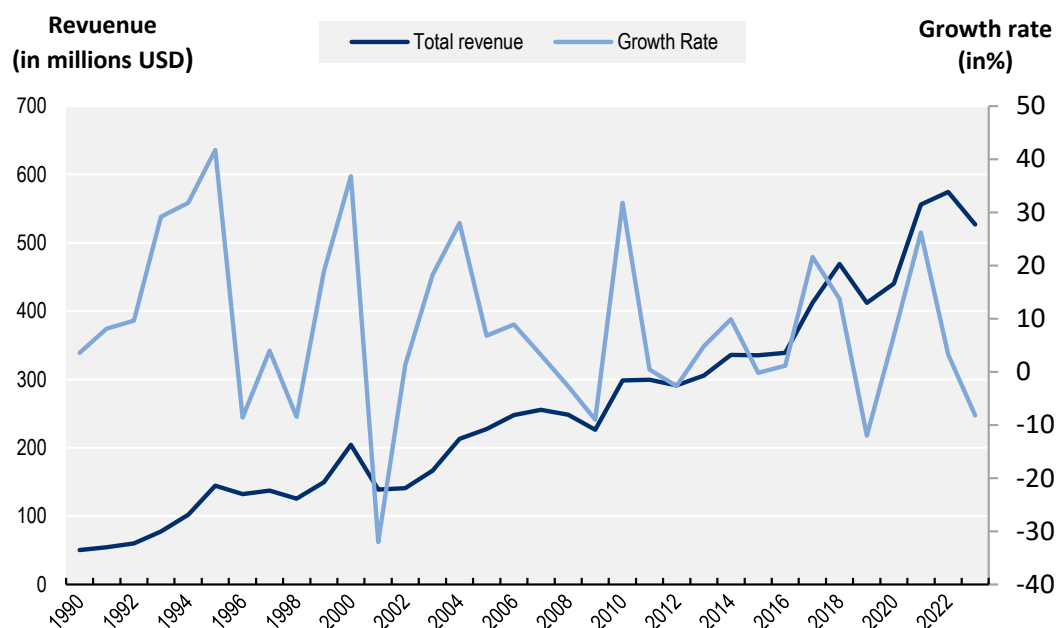
Source: (Semiconductor Industry Association (SIA), 2021^[46])

Over the past three decades, the semiconductor sector has experienced rapid growth and has had a substantial economic impact. The compound annual growth rate (CAGR) of this sector, at 10.7%, has far surpassed the global GDP growth rate of around 5% during this period. Performance improvements delivered by the semiconductors have fuelled enormous economic growth through the evolution of personal computers (PCs), online services, and the advent of smartphones. It is estimated that

semiconductor innovation directly contributed an additional USD 3 trillion in global GDP from 1995 to 2015, with an additional USD 11 trillion in indirect economic impact (IHS Inc., 2015^[47]).

The demand for semiconductors has even surged recently due to emerging industrial applications, including computing, artificial intelligence (AI), data centres, wireless communication, and other cutting-edge technologies. This increased demand has driven significant growth in the semiconductor sector, with sales reaching an all-time high of USD 574 billion in 2022 and expected to reach USD 611 billion in 2024 (Figure 2.8). The industry not only drives innovation and technological advancement but also contributes to countries' GDP and employment. For instance, in the US, the semiconductor industry directly employs over 250 000 workers and indirectly supports millions of additional jobs. It also contributes approximately USD 7 trillion, reflecting the sector's extensive economic impact. In countries like Korea and Chinese Taipei, the semiconductor sector is even more critical. Korea's semiconductor industry accounts for approximately 10% of its GDP, with companies like Samsung and SK Hynix leading global markets in memory chips. Chinese Taipei's dominance in wafer fabrication, especially through companies like TSMC, is pivotal to the global supply chain, providing over 60% of the world's foundry production capacity (Congressional Research Service, 2023^[48]).

Figure 2.8. Semiconductor market revenue worldwide from 1990 to 2024



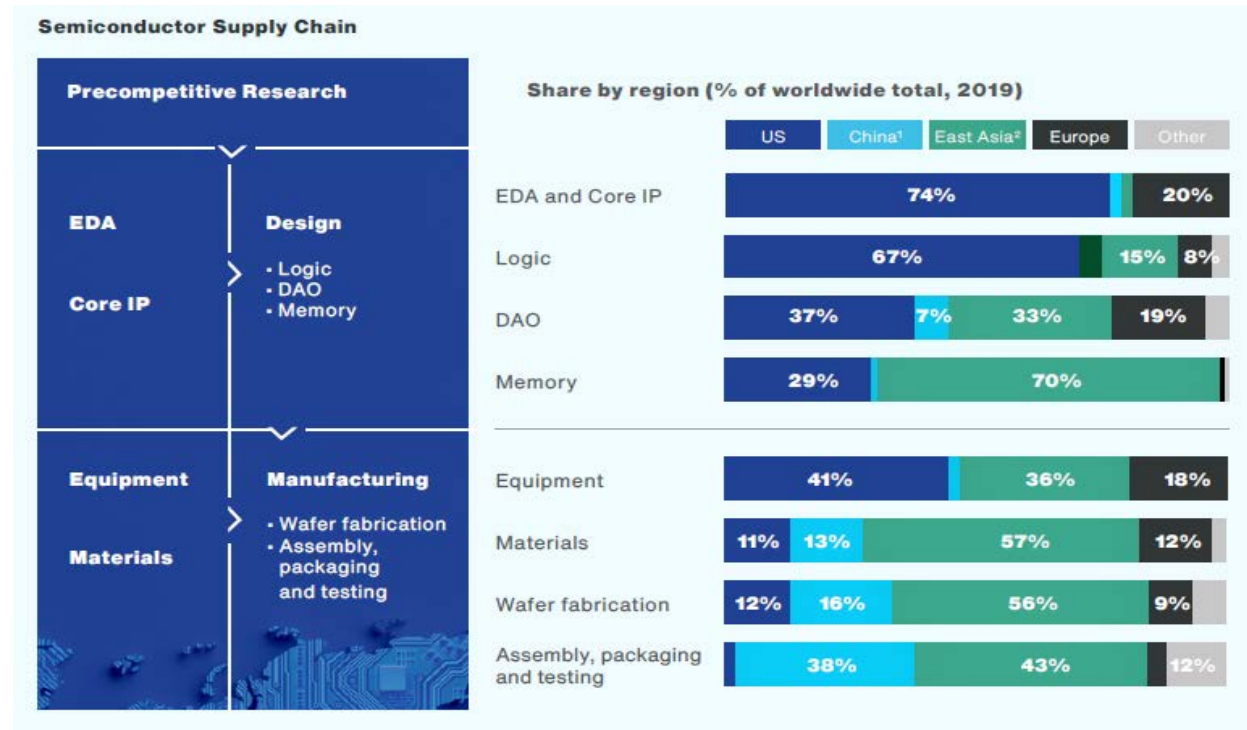
Source: OECD calculation based on World Semiconductor Trade Statistics (WSTS).

Fragmented and long supply chains in the entangled semiconductor eco-system

A defining characteristic of the semiconductor sector is its highly fragmented and complex global supply chain, with different countries specialising in specific stages of the value chain. Firms across various regions contribute to the processes of chip design, wafer fabrication, assembly, packaging, and testing, before chips are delivered to downstream manufacturers for final devices (Asian Development Bank, 2023^[49]). It is common that semiconductor chips cross international borders multiple times during production, with some estimates suggesting up to 70 cross-border movements for a single chip (Global Semiconductor Alliance, 2020^[50]). This gives a specific role to regions and to firms, including SMEs, based on their competitiveness. As shown in Figure 2.9, the ecosystem comprises chip producers, companies

for packaging and testing, as well as companies that manufacture the machinery and materials required for chip production. Fabless chip designers, like Nvidia, also play an increasingly important role with the advancement of AI technology. Different regions including the U.S., Europe, China, and East Asia including Korea and Chinese Taipei are key players in various stages of production.

Figure 2.9. Global semiconductor supply chain based on geographic specialisation



Note: 1. Mainland China, 2. East Asia includes Korea, Japan and Chinese Taipei

Source: (Semiconductor Industry Association (SIA), 2021^[46])

The early leaders in the semiconductor industry, large U.S. firms like IBM and Intel, internalised all tasks necessary for producing chips in their in-house fabs, known as integrated device manufacturing (IDM). Today, while the U.S. continues to lead in research-intensive areas such as electronic design automation (EDA) and chip design, countries in East Asia – particularly Chinese Taipei and Korea – dominate wafer fabrication, bolstered by heavy capital investment and advanced manufacturing technologies. Japan, once a leader in chip production, has specialised in equipment and materials, while in Europe countries like Germany and the Netherlands feature specialisation in manufacturing equipment. Although European countries still produce chips in specific segments like for the automotive sector, they heavily rely on import from Asia for advanced chips manufacturing. China's role is growing, particularly in assembly, packaging, and testing, where it leverages its vast manufacturing base, with substantial investments to expand its capabilities further along the value chain (Semiconductor Industry Association (SIA), 2021^[46]).

The majority of global semiconductor manufacturing capacity is concentrated in firms headquartered in the U.S. (33% in 2019), China (26%), Korea (11%), Japan (10%) and Chinese Taipei (9%) (Semiconductor Industry Association (SIA), 2021^[46]), but these shares can vary depending on the types of chips, such as Logic, Memory and DAO, reflecting regional specialisation within the industry. Over decades of specialisation, the semiconductor supply chain has become highly interdependent, as previously emphasised, with Chinese Taipei accounting for more than 60% of the global supply of certain types of chips. Recent disruptions, like the COVID-19 pandemic and geopolitical tensions, have highlighted the

concentrated nature of semiconductor manufacturing and the risk associated with it. With the semiconductors becoming increasingly vital across industries, this realisation now significantly influences national strategies and government policies aimed at preserving or enhancing their competitiveness, with each country or region seeking to reconfigure the global supply chain in its favour. In fact, a number of countries, including the U.S. and across the EU, have revised their strategies by investing in domestic semiconductor production to reduce dependency and strengthen supply chain resilience.

The Role of SMEs in the Semiconductor Ecosystem

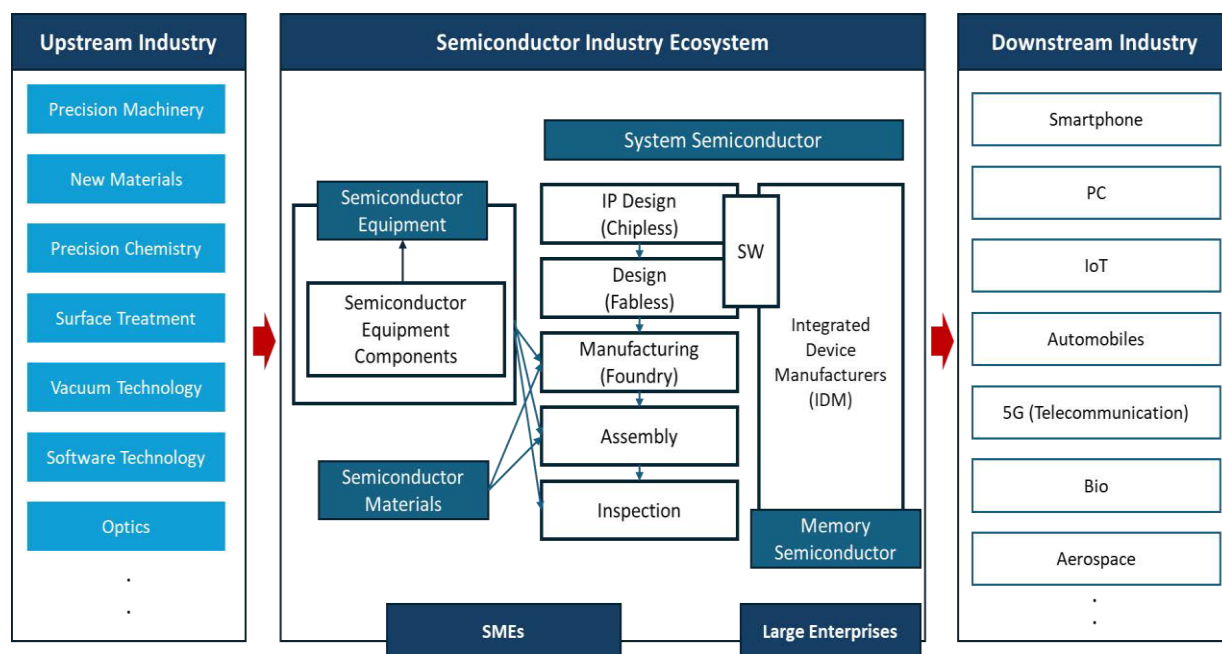
As strategies to reconfigure the semiconductor supply chain advance worldwide, SMEs within the ecosystem encounter both opportunities and challenges. While the capital-intensive nature of the semiconductor industry often limits the ability of SMEs to take on major roles, there are specialised niches where they can effectively contribute and play a critical part in the value chain.

Given the increasing complexity of technology, capital-intensive large companies play a dominant role in the sector. The fabrication process, for instance, is dominated by large companies that can afford the significant costs of building fabs and scaling production. Moreover, developments like Electronic Design Automation (EDA) and Process Design Kits (PDK) provide vital tools to chip designers but are often prohibitively expensive for smaller firms, limiting their innovation capacity and market expansion (Congressional Research Service, 2023^[48]). Finally, SMEs often rely on partnerships with larger firms, which can be a key driver of growth, as illustrated in Box 2.5, but which can also create a power imbalance, further restricting their ability to innovate independently. SMEs' small scale and limited resources often hinder their growth, forcing them to remain in specific niche markets (Jongwon Shin, 2020^[51]).

Despite often being under-recognised, SMEs play a crucial role in enhancing the flexibility and resilience of the semiconductor supply chain. They address gaps that larger firms may overlook, particularly in upstream segments, by supplying key components and offering specialised capabilities. Thanks to their agility, SMEs can innovate quickly and respond to niche market demands more effectively than larger players. For example, some SMEs, and startups in particular, focus on designing and developing energy-efficient chips, which are crucial with the emergence of AI, as computers need to rapidly process and store large amounts of data. Beyond innovation, SMEs also provide essential ongoing services such as maintenance, software updates, and operational support, which constitute a significant portion of their revenue in the semiconductor sector. A notable example is LAM Research, a major U.S. equipment provider that, in 2021, generated over USD 2 billion in revenue from servicing maintenance.

Further, SMEs play a crucial role in upstream activities such as in semiconductor manufacturing equipment and materials. SMEs have a key role as providers of critical raw components such as silicon wafers and photomasks, as well as specialised machinery like etching machines and chemical vapor deposition (CVD) equipment. In addition, while large firms like TSMC and Samsung dominate chip production, SMEs play a significant role in the design phase before fabrication, namely as fabless companies and design houses, as well as in back-end manufacturing processes such as packaging and testing, as shown in Figure 2.10.

Figure 2.10. The role of SMEs in the Semiconductor Ecosystem



Source: OECD desk research and illustration.

For example, ArchiTek Corporation, a Japanese SME, developed the AiOnlc, a high-performance, low-power AI chip designed for edge devices like IoT equipment, with applications in areas such as self-driving vehicles and hazard-sensing systems. The AiOnlc delivers GPU-level parallel processing with minimal power consumption, showcasing the crucial role SMEs play in driving technological innovation. SMEs are uniquely positioned to succeed due to their simpler organisational structures, which allow management's skills and ambitions to directly influence front-line operations (Arai, 2024^[52]). Moreover, their focus on small-lot production and niche markets enables them to identify and address latent industry needs, filling gaps in market demand from a distinctive perspective. A leading company like ASML began as a small enterprise and has grown into a critical supplier of photolithography machines that are crucial for advanced semiconductor manufacturing. This equipment is essential for the precise and complex processes required in semiconductor fabrication. Similarly, GlobalWafers, a Chinese Taipei-based SME, has leveraged its specialisation in silicon wafers to become a critical supplier in the global semiconductor supply chain (Box 2.5). These examples show how SMEs, through specialisation and innovation, can build competitive edge in the industry. SMEs are also key players in niche markets in the manufacturing process, such as advanced packaging, which is becoming increasingly important as the demand for stronger and more efficient semiconductor devices grows.

Box 2.5. GlobalWafers: a successful SME in the Semiconductor Ecosystem

GlobalWafers has grown from a small enterprise into a major player in the global semiconductor supply chain by specialising in silicon wafer production. As of 2023, GlobalWafers held approximately 18% of the global silicon wafer market, making it one of the top suppliers worldwide. The global silicon wafer market was valued at around USD 15.79 billion in 2023, with strong growth expected as demand for advanced semiconductor devices continues to rise.

Strategic Partnerships and Market Reach

- **Partnerships:** A key driver of GlobalWafers' growth has been its ability to form strategic alliances with major semiconductor companies, including Intel, TSMC, and Samsung, which together account for nearly 60% of global chip production.
- **Role in the Supply Chain:** By leveraging its niche expertise, GlobalWafers supplies 200 mm and 300 mm silicon wafers to these industry leaders, ensuring their manufacturing processes run smoothly.

Market Impact and Global Position

- **Market Share:** As of 2023, GlobalWafers held 18% of the global silicon wafer market, contributing significantly to the market's total valuation of USD 15.79 billion annually.
- **Production Capacity:** The company operates 17 manufacturing facilities across 10 countries, providing a global reach to support its position as a critical supplier in the semiconductor industry.
- **Industry Contribution:** GlobalWafers' commitment to producing high-quality wafers ensures its vital role in the semiconductor supply chain, with silicon wafers accounting for 40% of the cost of a finished semiconductor chip.

Source: OECD desk research and (Business Research Insight, 2024^[53]).

The semiconductor industry is navigating a period of intense global competition, as major countries strive to secure and restructure their supply chains. This pressure is prompting a reconfiguration of long-established global networks. At the same time, emerging technologies – such as AI, big data, the metaverse, and autonomous vehicles – are creating new growth opportunities. While these trends introduce added complexity, including higher production costs and potential supply chain disruptions, they also present openings for SMEs to strengthen their market position. By targeting niche segments where they hold a competitive advantage and forming strategic partnerships with larger firms, SMEs can enhance their resilience and relevance in this evolving landscape.

Transformative changes in the semiconductor sector

Digitalisation and ever-increasing demand for semiconductors

The global semiconductor market is positioned for sustained growth, propelled by the digitalisation and the rapid advancement of transformative technologies. Notably, the recent expansion of artificial intelligence (AI) across various industries has led to an unprecedented demand for more powerful and specialised semiconductor chips, fuelling the growth of the sector. From 2012 to 2022, global semiconductor sales doubled to USD 574 billion and, by 2030, it is projected to surpass USD 1 trillion, effectively doubling its current size again (BCG and SIA, 2021^[54]).

The high demand for semiconductors not only significantly boosts the profitability of the industry but also underpins advancements in crucial sectors such as drones, robotics, telecommunications, and aerospace. These industries, which often have military applications, are strategically important and are likely to receive continued support through national industrial policies. Given its critical role in enabling new technologies, the semiconductor industry holds tremendous potential for future growth supported by the governments, which impacts the direction and speed of the sector's development. With the sector's rapidly growing demand, SMEs have increased opportunities to find niches where they can demonstrate their competitiveness, such as in fabless operations, design houses, or packaging roles.

Drive towards resource and energy efficiency

The electronics industry accounts for 4% of global greenhouse gas (GHG) emissions. Within this industry, semiconductor manufacturing is particularly energy-intensive, and relies on complex chemical processes, which contribute to 0.3% of total global emissions (BCG, 2023^[55]). Furthermore, more complex packaging and materials increase the overall environmental footprint of the industry.

As the demand for semiconductors accelerates and the fabrication of advanced chips becomes more energy intensive, the industry faces mounting pressures to implement energy-efficient processes. Currently, a single semiconductor fab can consume as much electricity as a small city. For example, TSMC's advanced chip fabs in Chinese Taipei consumed about 7.9 billion kWh of electricity in 2020, equivalent to 4% of Chinese Taipei's total power usage (TSMC, 2022^[56]). The energy consumption in these fabs primarily comes from running the equipment necessary for the semiconductor manufacturing processes, as well as maintaining cleanroom environments that are essential for high-quality chip production. Some estimates suggest that more than 80% of the semiconductor industry's emissions come from electricity consumption, much of which is still generated from non-renewable sources (BCG, 2023^[55]).

To address these challenges, major industry players have been exploring various decarbonisation strategies. For example, TSMC has committed to use 100% renewable energy by 2050. Samsung has invested in energy-efficient technologies to reduce the energy consumption of its fabs, which has resulted in a reduction of GHG emissions per revenue unit by 56% from 2009 to 2019 (Samsung, 2024^[57]). Many companies are retrofitting their existing fabs with more energy-efficient equipment, including better cooling systems and energy recovery solutions. Since one of the key sources of emissions in the sector is the use of perfluorinated compounds (PFCs) in the etching and cleaning processes, companies like IBM have been working on replacing PFCs with less harmful chemicals and implementing recycling systems to capture and reuse these gases (IBM, 2008^[58]).

Against this background, SMEs in the supply chain are also faced with the need to rethink their manufacturing processes, materials sourcing, and the overall lifecycle management of semiconductor products.

Geopolitical risk, technological advancement and GVC reconfiguration

COVID and geopolitical developments

The COVID-19 pandemic created massive disruptions worldwide leading to severe chip shortages. Along with this catalyst, trade tensions, together with the recognition of the importance of manufacturing industry to the national economy, have been driving geographic reconfigurations of global value chains for the semiconductor sector. The high concentration of semiconductor production in East Asia - advanced chips under 10 nano meters are currently 100% produced in the region, 98% in Chinese Taipei, 2% in Korea - originally driven by economic efficiency, is now regarded as a major vulnerability. The historical tensions between Chinese Taipei and China, as well as between North Korea and Korea, could turn into critical threat, with major consequences for the global semiconductor supply chain. Consequently, the reconfiguration of global value chains has become a strategic priority in the industry.

The value-added cycle of the semiconductor value chain is changing

For decades, in the semiconductor sector, the distribution of value added along the product's life cycle has followed the so-called “smile curve”, with the R&D sector capturing the highest added value. Leading countries like the U.S. have historically retained these activities domestically, protecting them through intellectual property (IP) regimes, while outsourcing manufacturing activities to other regions like East Asia (BCG and SIA, 2021^[54]). However, recent shifts in technology have altered these dynamics. With advancements in AI, big data analytics, and simulations, semiconductor design has become more streamlined, reducing the development cycle. This has diminished the complexity and relative value of design activities. On the other hand, manufacturing process technology has become much more complex and intricate due to the demand for ultra-fine process technologies (like sub-10nm nodes) and advanced packaging. These technology shifts have increased the value captured by manufacturing, especially in advanced fabs, which require substantial capital investment and technical expertise. The “reverse smile curve” argument, which highlights the increasing value of the manufacturing and packaging, explains the trend in many countries to reprioritise domestic capacities in this part of the value chain (NBER, 2024^[59]).

The ongoing reconfiguration of GVCs and changing roles within the semiconductor supply chain present both challenges and opportunities for SMEs. On the one hand, this restructuring allows SMEs to seek incorporation into new supply chains, which can give them access to a broad customer base and the chance to learn from the practices of larger firms in competitive markets. However, this participation also brings substantial challenges, as SMEs may struggle to establish themselves and face difficulties in adapting to rapid technological changes, higher transaction costs, and competition from larger firms in R&D and innovation (ADB, 2015^[60]). As the global landscape evolves, government policies can play an important role for enabling SMEs to adapt to new market conditions and position themselves within the evolving value chain.

Policy responses to global megatrends in the semiconductor sector

Historically, semiconductors have been central to industrial policies, given their critical role in enabling technological progress and economic growth. Today, the policy focus on the industry reflects several goals: fostering economic growth, enhancing international competitiveness, bolstering resilience, and ensuring national security (NBER, 2024^[59]).

For decades, the sector operated with well-established roles across the global value chain, supported by a network of diverse companies, both large and small. As geopolitical shifts and technological advancements are disrupting this balance, prompting companies to reconsider sourcing, production, and market access, some advanced countries have developed industrial policies to secure global leadership in the semiconductor sector. Such national strategies are redefining roles and influencing the global distribution of value across the industry. The impact of these evolving policies is extensive, crossing borders and affecting corporations of all sizes, both large multinational firms and SMEs.

Legislation and strategic support

Countries around the world are in a fierce race to secure their status as global semiconductor powerhouses. As digitalisation accelerates and semiconductors remain critical to this transformation, advanced economies – many of which had previously experienced a decline in manufacturing due to the rise of efficient GVCs – are now introducing major industrial policies to strengthen their manufacturing capabilities in the semiconductor sector. In 2023, approximately 2 500 industrial policy interventions were implemented globally, with a significant portion driven by the U.S., the EU and China, which accounted for almost half of all new industrial measures, targeting advanced technologies such as semiconductors and their critical components like rare minerals (IMF, 2024^[61]).

Over 2010-2023, 11 jurisdictions (counting European countries as a group) had implemented at least one new policy in the semiconductor sector. The five established producers – China, Europe, Japan, Korea, and the U.S. – provided the most intensive support both in terms of the number of policies and monetary values of their spending, with most of these policies announced after 2020 (NBER, 2024^[59]). This indicates that semiconductor sector policies are primarily driven by countries already leading in the field. However, the trend of implementing comprehensive national policies is a relatively recent development.

The U.S. has been especially active in promoting the semiconductor sector as a national priority, with policies aimed at reinforcing the domestic manufacturing capacity, reducing dependency on manufacturing and assembly in Asia. This was notably a main objective of the U.S. CHIPS Act, implemented in 2022. While similar approaches have been adopted globally, such as the EU CHIPS Act, or K-CHIPS Act, the U.S. CHIPS Act stood out for its scale, particularly in the funding of domestic manufacturing. While it primarily supported large-scale investments by major semiconductor manufacturers, it was also expected to benefit SMEs indirectly by increasing demand for specialised suppliers and service providers across the semiconductor value chain, as well as by creating greater opportunities to participate in innovation ecosystems and collaborative R&D activities associated with expanded investment. Evidence on the scale of these effects is still emerging, with recent review by the United States Government Accountability Office (GAO) showing that funded projects were distributed across multiple stages of the semiconductor supply chain, rather than being concentrated solely in fabrication, suggesting the potential for broader impacts across related firms and suppliers⁶.

In 2023, the EU CHIPS Act was introduced, with the goal to double Europe's share of global semiconductor production from 10% to 20% by 2030. While Europe has traditionally excelled in semiconductor materials and equipment, with companies like ASML, its chip production capacity has lagged, mainly concentrated on less advanced chips. To address this gap, the EU CHIPS Act aims to foster development of advanced semiconductor fabs, particularly for sub-10nm nodes, thus positioning the EU as a global hub for next-generation semiconductors. Securing leadership in R&D is a main objective, including by leveraging the strong research base in fields like nanoelectronics and quantum computing.

Box 2.6. Comparison of the U.S. and EU CHIPS Acts

Since 2025, implementation of the U.S. CHIPS Act has been subject to review and adjustment. The following comparison focuses on the main design features of the U.S. and EU semiconductor policy frameworks, noting that aspects of the U.S. approach may continue to evolve.

The U.S. CHIPS Act was introduced in 2022 to respond to major megatrends in the semiconductor sector, and to enhance national competitiveness and industry resilience. Similar initiatives have followed in other parts of the world, including the EU, whose CHIPS Act entered into force in 2023. While countries like Korea have announced national-level strategies, these are generally smaller in scale and budget. All “CHIPS Acts” share similar strategic goals, such as reducing dependence on offshore semiconductor production, enhancing supply chain resilience, and growing a skilled workforce, but they can differ in several aspects. Some of the major differences between the U.S. and EU Acts are outlined below:

New vs. Existing Funding

The amount of direct public funding provided is roughly comparable. However, while the U.S. CHIPS Act had allocated new federal funding of around USD 52 billion, most of the EU CHIPS Act's EUR 43 billion budget has been sourced from existing EU programmes, like Horizon Europe and the Digital Europe Programme.

Subsidy Purpose

EU competition law prohibits subsidies unless they meet certain exceptions, such as aiding regional development or promoting innovation (e.g., 'first-of-kind' rule). This means that EU CHIPS Act subsidies must be thoroughly approved.

Tax Incentives

The U.S. CHIPS Act had provided new federal tax incentives for investment, in order to boost the financial attractiveness of building facilities, while the EU CHIPS Act does not include tax benefits.

Institutional Complexity

The U.S. CHIPS Act funding was relatively straightforward, involving a bilateral agreement between the Department of Commerce and industry recipients. In the EU, companies need to secure commitments from member state governments and then gain approval from the EC under state aid rules.

Source: OECD desk research and (CSIS, 2024^[62])

Japan, Korea, and China have also introduced national level master plans and relevant legislation. Japan's Semiconductor and Digital Strategy, launched in 2023, aims at increasing sales of semiconductor three times the current level, from JPY 5 trillion in 2020 to JPY 15 trillion in 2030. Korea, a leading memory chip producer, initiated the K-semiconductor Strategy in 2021, which evolved into the Semiconductor Mega Cluster Strategy in 2024, to consolidate its position and expand its leadership beyond memory chips to include logic chips and fabless design. Domestic giants like Samsung and SK Hynix have pledged a huge investment of KRW 510 trillion by 2030, with the government offering tax deductions of 40-50% for R&D activities. China, on the other hand, has pursued a state-led push over the past decades, largely through its Five-Year Plans and the National Integrated Circuit Industry Investment Fund (commonly known as the Big Fund). These initiatives aim to increase domestic production and reduce dependency on foreign technologies, reinforcing China's position in the global semiconductor landscape.

Table 2.8. Timeline of major policies

Year	Policy	Country	Budget
2014	Integrated Circuit Development Outline	China	-
2014	National Integrated Circuit Industry Investment Fund (Big Fund) Phase 1	China	-
2016	13 th Five-Year Plan	China	
2019	Artificial Intelligence Strategy	Korea	USD 1 billion
2019	National Integrated Circuit Industry Investment Fund (Big Fund) Phase 2	China	USD 29 billion*
2020	14 th Five-Year Plan	China	-
2020	Integrated Circuit Development Outline	China	-
2020	Program for Promoting Investment to Strengthen Supply Chains	Japan	USD 3.5 billion
2021	National Recovery and Resilience Plan	Germany	USD 1.7 billion
2021	Specified Semiconductor Fund (along with Green Innovation Fund and Economic Security Fund)	Japan	USD 15 billion
2021	K-Semiconductor Strategy	Korea	USD 13 billion
2021	Export control licensing	US	-
2022	Electronique 2030	France	USD 5 billion
2022	CHIPS Act	US	USD 52 billion
2023	EU CHIPS Act	EU	USD 47 billion
2024	Creation of the Semiconductor Mega Cluster	Korea	N/A
2024	National Integrated Circuit Industry Investment Fund (Big Fund) Phase 3	China	-

Note: The table is not comprehensive but rather a list of selected policies.

Source: OECD desk research and (NBER, 2024^[59])

Investment and funding programmes

In the semiconductor sector, most firms receive various forms of government financial support (OECD, 2019^[63]). This includes direct budgetary support, such as direct transfers, tax reduction, and subsidised inputs, as well as financial assistance through lower interest rate or access to favourable funding sources. Traditionally, tax incentives targeting R&D were the most common type of support due to their potential for generating widespread benefits. However, in recent years, policy priorities have shifted towards direct subsidies aimed at expanding domestic production. This shift, accelerated since 2020, reflects a strategic effort to reduce dependence on offshore manufacturing and address supply chain vulnerabilities.

Establishment of large-scale funds and direct subsidies

The creation of large-scale investment funds is the cornerstone of recent government initiatives. These funds, often backed by both public and private capital, aim to support the semiconductor companies and related infrastructure. While governments typically provide the bulk of the capital, private sector involvement is encouraged to bring in expertise, innovation, and additional funding.

In the case of the U.S. CHIPS Act, the largest share of the USD 52 billion budget was allocated for the establishment of new production facilities onshore. The fund also targeted R&D, supply chain security, and workforce expansion and training. USD 39 billion was earmarked as direct subsidies for companies building fabs in the U.S. Since 2025, implementation of the Act has been subject to review and adjustment, including the reassessment of some funding agreements.

As part of the EU CHIPS Act, Europe has launched the Important Projects for Common European interest (IPCEI) framework with a budget of EUR 43 billion, redirected from existing EU-funded programmes, with the expectation that this will spur a roughly equal amount of private investment (CSIS, 2024^[62]). Reportedly, some EUR 30 billion are intended to support the establishment of advanced fabs, specifically aimed at producing chips with sub-10nm nodes. The funding targets “first-of-kind” projects in the EU, involving innovative technologies. For example, in France, 12 projects have been approved in the framework of IPCEI, with EUR 7 billion allocated for the establishment of about ten factories in the electronics industry supply chain. These projects also target specific applications of microelectronics in multiple sectors, including the telecommunications and the automotive sector. The initiatives are also expected to support researchers, SMEs and start-ups through financing and partnerships with research centres and key ecosystem players (Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2023^[64]). A EUR 2 billion measure to support STMicroelectronics for the construction and operation of an integrated chip manufacturing plant in Italy was also approved in May 2024 (European Commission, 2024^[65]).

Japan's specified Semiconductor Fund, valued at JPY 1.7 trillion, targets investment in technologies like AI and quantum computing. The fund is further supplemented by the Green Innovation Fund and Economic Security Fund to enhance the sector's sustainability and security. Several projects are implemented under the line “Ensuring Domestic Production Bases for Advanced Semiconductors”, which was allocated JPY 617 billion (2021) and JPY 450 billion (2022). Notably, the government pledged JPY 476 billion for TSMC's new factory in Kumamoto and JPY 330 billion for Rapidus, a state-supported foundry startup. These investments aim to restore Japan's position as a leader in advanced chip production.

Tax incentives and concessions

Historically, tax incentives have been a primary tool for governments to provide financial support to the semiconductor industry. Tax concessions can take the form of direct tax credits for R&D and equipment purchases, or broader tax-related incentives like property-tax abatement, special reductions in rates of corporate income tax, and investment tax credits. Tax-related support used to make up 90% of the total

budgetary support provided to firms in the industry (OECD, 2019^[63]), although its relative weight in the industrial policy instrumentation has reduced in recent years.

Under the K-Semiconductor Strategy, Korea offers some of the world's most generous tax incentives for semiconductor companies, with up to 40% tax credits for R&D expenses, and 6% to 20% credits for capital investments, depending on the size of the company and the nature of the project. These incentives also extend to equipment purchases, especially benefiting fabless SMEs, as illustrated in Box 2.7, allowing smaller player to remain competitive in the global market.

Japan also offers tax incentives for investments in R&D and capital expenditures. These measures are especially focused on advanced technologies like next-generation nodes, aiming to boost the domestic production of cutting-edge chips and related technologies.

As part of the U.S. CHIPS Act, a 25% investment tax credit was introduced for qualifying investments in semiconductor manufacturing facilities and equipment. Together with direct funding and loans, this measure aimed to lower the cost of establishing, expanding, and modernising semiconductor production capacity in the U.S.

Other significant players, such as China, Chinese Taipei, and Singapore also offer competitive tax incentives to grow and sustain their global leadership in the sector. Common measures include tax exemptions. China provides a five-year tax holiday followed by a reduced tax rate after the initial period. Singapore offers corporate tax exemptions for up to 15 years for the companies undertaking high-value manufacturing or R&D activities. Chinese Taipei has offered generous tax credits that could cover as much as 35% of the companies' capital expenses and 13% of their equipment purchases (BCG and SIA, 2021^[54]). However, the incentives have been reduced after 2009-2010.

Favourable financing and loans

In addition to grants and tax incentives, many governments provide low-interest loans and other favourable financing to facilitate semiconductor investments. While tax concessions can benefit both domestic and foreign firms, support through the financial system in the form of below-market or favourable financing create a favourable environment for domestic enterprises (OECD, 2019^[63]). The below-market loan and other forms of support through the financial system often use state-owned financial institutions as intermediaries and are more prevalent in economies where the state plays a strong role.

For example, Chinese State-owned enterprises (SOEs) and firms connected to government networks benefit from preferential access to credit, with favourable terms and low-cost financing provided through Chinese state banks (OECD, 2019^[63]). In Korea, there is also a special financial support for the semiconductor sector, including KRW 17 trillion loan programme and the creation of a KRW 1.1 trillion fund to support the semiconductor ecosystem under its Semiconductor Mega Cluster Strategy (Ministry of Trade, Industry and Energy (MOTIE), 2024^[66]).

R&D support and technology transfer

At the R&D stage, government involvement is very common, as it addresses the perceived market failure where private firms tend to underinvest in R&D without public support. The semiconductor sector is one of the most R&D-intensive fields, alongside industries like pharmaceuticals, aerospace, and software development (OECD, 2019^[63]). To promote R&D, governments employ a variety of tools, including direct research grant and tax incentives, as previously discussed. Other instruments include public-private partnerships (PPPs), both within and across countries, which have played a significant role in the historical development of the semiconductor sector. This development has been supported by governments' as well as private firms' willingness to engage in technology transfer activities.

The EU emphasises public-private collaboration through programmes like Horizon Europe and joint undertakings, such as the EU Chips Joint Undertaking. With an expected budget of EUR 11 billion until 2030, it aims to develop cutting-edge semiconductor technologies. It will support the development of advanced technology and engineering capacity for quantum chips and establish a network of competence centres to facilitate the transfer of knowledge from the lab to the fab. At the country level, there are several examples of co-operative approaches, such as Germany's Semiconductor-X, a sub-programme of its broader Manufacturing-X initiative. In Semiconductor-X, collaboration between industry leaders and research partners focuses on developing digital twins for the semiconductor sector based on Catena-X and Gaia-X architectures. The digital twins simulate critical supply and value chain segments, while AI-based analysis aims to help companies address industry-specific challenges, such as high throughput times, varying process yields and high product variance.

Technology transfer is often facilitated through FDI and business collaborations, which have been crucial in the development of semiconductor industries worldwide. There is virtually no country where a domestic semiconductor industry developed without substantial foreign technology transfer (NBER, 2024^[59]). In the highly fragmented semiconductor supply chain, firm-to-firm relationships between buyers and sellers play a critical role in facilitating technology transfer. This exchange of knowledge has been essential for the sector's growth, and governments have implemented policies to attract foreign companies with advanced technologies to foster this development within their borders.

Historically, public agencies have facilitated extensive international technology transfer, as seen in the example of Korea. The Electronics and Telecommunication Research Institute (ETRI) played a key role in coordinating R&D efforts between public researchers and the private sector. ETRI conducted basic research itself, while working closely with the private sector, using the tool of public procurement. It successfully encouraged foreign firms to supply the market and initiate technology development in the institute, which was then diffused into the private sector, fostering innovation. However, in most cases recent policies have not prioritised this type of approach.

Advancing the development of resource-efficient chips

The semiconductor manufacturing process is highly energy-intensive and water-demanding. As the use of semiconductors increases across a wide range of applications, the energy demand from semiconductor-enabled products also rises. Evidence shows that global energy consumption from semiconductor-enabled products has been doubling every three years since 2010 (U.S. Department of Energy, 2022^[67]). To mitigate this impact, the energy efficiency of chips would also have to double just to keep pace with growing consumption.

In line with the European Green Deal, the EU has taken steps toward integrating resource efficiency into semiconductor production. Historically, the semiconductor industry has not been one of the major contributors to GHG emissions in Europe. However, with the implementation of the EU CHIPS Act, Europe's share of global semiconductor production is expected to grow from 10% to 20% by 2030. This growth could lead to an eightfold increase in emissions from the sector, potentially surpassing those of other emission-heavy industries (Hess, 2024^[68]). To address this, the EU CHIPS Act promotes energy-efficient chip design and sustainable manufacturing practices. Complementing these efforts are policies like the F-gas regulation, which targets the reduction of harmful fluorinated gases used in semiconductor manufacturing, and the proposed ban on PFAS (commonly referred to as "forever chemicals"), expected by 2026 (Hess, 2024^[68]).

In 2022, the U.S. Department of Energy (DOE) introduced the Energy Efficiency Scaling for 2 Decades (EES2) initiative to address the rising energy consumption within the semiconductor industry. This programme has gathered over 60 organisations across private industry, national labs, and academia to steer research and collaboration on energy-efficient microelectronics, with the goal of increasing

semiconductor energy efficiency 1 000-fold over the next 20 years, with interim goals of 10x by 2030 and 100x by 2036 (Snyder, 2023^[69]).

Korea has also introduced initiatives to enhance energy efficiency and reduce the environmental footprint of its semiconductor sector. The country plans to power the fabs in its new Semiconductor Cluster entirely with renewable energy, despite challenges related with the current low rate of renewable energy usage and the need for an additional 10 GW of electricity.

In addition to specific sectoral policies, general policies applicable to the broader manufacturing industry – such as carbon trading, tax incentives for renewable energy usage, and strict emission standards – are also being implemented in many countries. The private sector has also pledged to address the industry's intensive resource use. Companies like Intel, Samsung, and TSMC have established their own strategies, committing to operate their facilities on 100% renewable energy and to recycle water used in production.

Supply chain integration and cluster policies

Recent policy initiatives have a strong focus on domestic production. Governments are fostering clusters, geographically concentrated ecosystems where research, manufacturing, design, and assembly occur in close proximity, benefiting from shared infrastructure, talent, and supply chains. Since an efficient infrastructure is vital for regional clusters to succeed, governments are investing in transportation networks, energy supply, and logistics to ensure that manufacturing sites are seamlessly connected to needed material suppliers and global markets. The cluster, in turn, provides jobs and revives the regional economy, including SMEs, supporting their integration in the supply chains.

A compelling example includes the Chinese Taipei semiconductor industry cluster in Hsinchu Science Park, which supports approximately 150 000 jobs, attracting both local and international talent with specialised skills. The proximity of firms in the park creates strong supplier linkages and drives efficiency, enabling SMEs in the region to integrate high-tech supply chains, favouring technology adoption, skills development and new business ventures (Chen, Lin and Chu, 2013^[70]; Shivakumar, Wessner and Howell, 2023^[71]).

Korea is establishing a Semiconductor Mega Cluster in Yongin, near the capital aimed at securing USD 465 billion in private investment from the country's semiconductor conglomerates, Samsung and SK Hynix. The cluster will host 16 fabs, including 2 research facilities, and will generate substantial employment. This policy also aims to address weaknesses in the Korean semiconductor industry, which currently has a supply chain self-sufficiency rate of 30%, with the majority of essential materials, equipment, and technologies sourced from outside the country. By strengthening fabless SMEs, supported by USD 18 billion in financial loans and a USD 224 million Semiconductor Ecosystem Fund, the country aims to increase self-sufficiency rate to 50% by 2030, to increasing local capacity to manufacture key semiconductor components and materials (Ministry of Trade, Industry and Energy (MOTIE), 2024^[66]).

Japan has large-scale domestic investment projects in many regions in partnership with private companies. Prime example is the TSMC-Kumamoto project, whereby the Japanese government pledged around JPY 476 billion, which represents half of the total cost of the Kumamoto plant (Reuters, 2023^[72]). This financial backing is part of Japan's broader effort to bolster domestic semiconductor manufacturing and reduce its reliance on imports including government support projects for overseas supply chain diversification (re-shoring and near-shoring) from China, but also to revive regional SMEs by incorporating them into the supply chain.

One of the key pillars of Japan's supply chain policies for critical materials, as outlined in the Economic Security Promotion Act of May 2022, includes financial support provisions. These provisions encompass subsidies from entities such as the national research and development agency NEDO, the Japan Organisation for Metals and Energy Security (JOGMEC), two-stage loans through the Japan Finance Corporation, and credit guarantees for SMEs (Kim, 2023^[73]). The Japan Bank for International Co-

operation (JBIC) heightened efforts to support companies along the supply chain, including overseas subsidiaries of Japanese SMEs through loans to finance the acquisition of resources, infrastructure or M&A, facilitating resources for their international growth (JBIC, 2023^[74]).

Implications for SMEs of recent policy developments in the semiconductor sector

Recent national-level strategies have increasingly focused on expanding domestic production and enhancing its global competitiveness. This shift, which reflects in heightened fragmentation of the global supply chains, also creates market opportunities for local SME suppliers, as they benefit from increased demand for components. This in turn can generate the opportunity to better negotiate terms, pool resources, access new technologies and achieve economies of scale (OECD, 2024^[7]). However, specific support for SMEs within the semiconductor sector remains relatively limited. Most countries prioritise overarching, national-level policies, often aimed at attracting large corporations, such as through substantial investment incentives, with the expectation that SMEs will indirectly benefit through supply chain opportunities. While the trickle-down effect is intended to create opportunities for smaller businesses, this approach often overlooks the need for direct, targeted support mechanisms to help SMEs navigate the complexities of the semiconductor industry. The lack of a SME lens in industrial strategies risks leaving smaller companies struggling to compete with dominant players in the market and missing opportunities to integrate fast-evolving supply chains.

Additionally, the resurgence of subsidies and industrial policies has raised concerns about a potential “subsidy race” across countries, as well as distortions and inefficiencies, if resources are channelled toward less efficient firms or favour larger incumbent corporations. Such outcomes risk further marginalising SMEs.

While SME-specific programmes in the semiconductor industry are rare, some countries have implemented targeted initiatives to support smaller firms. Policies with a regional collaboration element – emphasising local hubs and tailored support for SMEs – have the potential to help smaller companies secure new contracts and increase their competitiveness.

Korea offers a detailed and sector-specific approach, particularly for fabless SMEs. Under its K-Semiconductor Strategy and Semiconductor Mega Cluster plan, Korea provides subsidies, technical support, and opportunities for collaboration with larger firms such as Samsung and SK Hynix. Chinese Taipei, home to TSMC, also offers a range of programmes aimed at fostering technology development among SMEs. These programmes focus on strengthening the chip design ecosystem, offering technical assistance, and promoting partnerships between SMEs and major foundries like TSMC.

Europe has taken a more nuanced approach in supporting SMEs, with specific programmes designed to foster innovation among smaller firms. While broader national policies may still prioritise large corporations, a number of countries have introduced SME-targeted support in the form of subsidies and tax incentives (see *country profiles on France and Germany*), with the aim to spur their investment and competitiveness.

Box 2.7. Case study: Korea's Semiconductor Mega Cluster Strategy

Korea has introduced and implemented the “Semiconductor Mega Cluster Strategy”, which involves all aspects of semiconductor development, from establishing local infrastructure powered by renewable energy to fostering private investment with a focus on integrating SMEs into the supply chain and supporting startups. The strategy also includes R&D programmes and labour training in collaboration with universities and global networks.

Currently, there are 19 production fabs and 2 research fabs in operation. By 2047, the plan envisions adding 16 new fabs (13 production fabs and 3 research fabs) through private investment of KRW 622 trillion. By 2030, the mega cluster is expected to achieve a production capacity of 7.7 million units per month.

Objective: Build the world's largest semiconductor cluster, enhancing Korea's industrial competitiveness and promoting local economic growth. The primary goals are to: 1) achieve a 10% market share in the semiconductor system (logic chips) market, and 2) attain 50% self-sufficiency in the supply chain.

Infrastructure: Ensure the timely provision of critical infrastructure, such as electricity and water. Plans include supplying 10 GW of electricity and 1.1 million tons of water per day, with expedited approval process to accelerate infrastructure development. Construction times are expected to be reduced by 30%.

Investment Environment: Increase tax deductions for investments up to 25% with the commitment of abolishing “killer regulations” that hinder the development of advanced industries. The initiative is backed by KRW 622 trillion (USD 470 billion), with major contributions from Samsung and SK Hynix.

Sustainability Focus: Prioritise the integration of renewable energy into the semiconductor sector with a goal to operate fabs on 100% renewable energy. The initiative includes building energy-efficient fabs to align with global sustainability trends.

SME Support: Focus on integrating SMEs into the semiconductor supply chain is key to achieve a 50% self-sufficiency rate by 2030, with an emphasis on equipment and materials. Initiatives include improving networking opportunities, expanding opportunities for prototype manufacturing, and providing financial support such as tax incentives and low-interest loans for SMEs. The goal is to nurture 10 fabless companies in the global top 50 by 2030, and foster 100 semiconductor startups by 2027 through designated funds.

Workforce Development: Various programmes to train specialists at different levels, including the establishment of specialised semiconductor graduate schools. Continue to strengthen the global co-operation with key countries like the U.S., Japan, and the EU, along with engaging in international research projects and training programmes.

Source: (Ministry of Trade, Industry and Energy, 2024^[75])

Machinery Sector

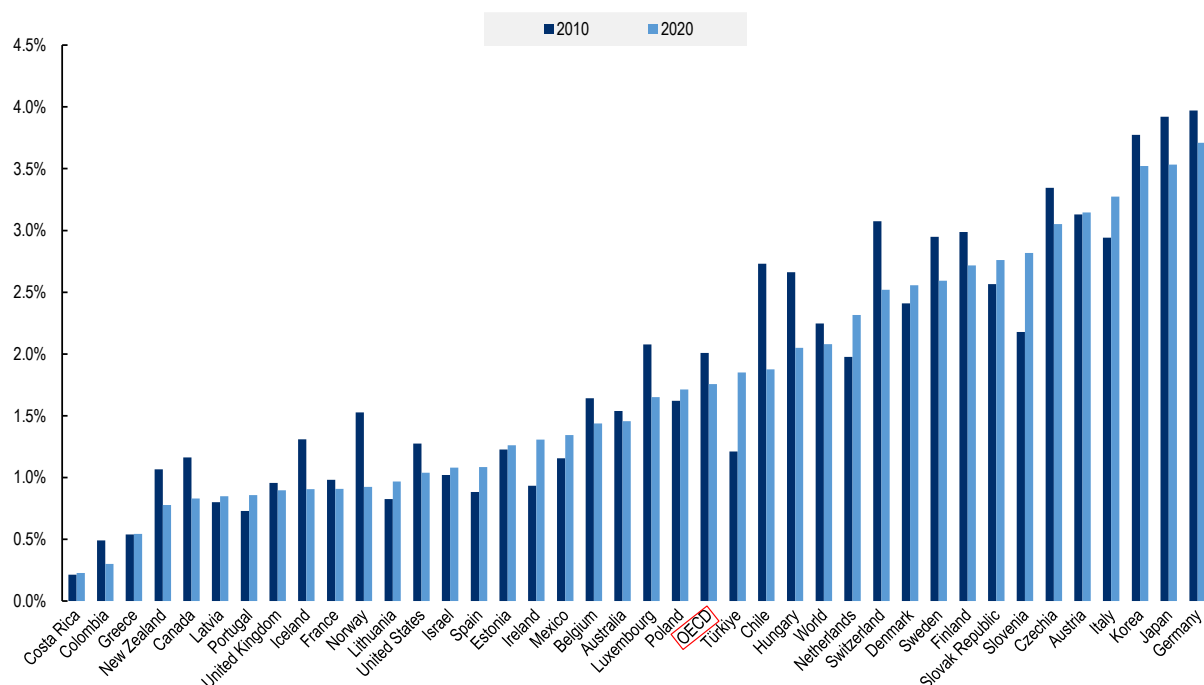
Machinery sector, at the core of the ongoing digitalisation of manufacturing processes

The machinery and equipment manufacturing sector is a cornerstone of the broader manufacturing ecosystem, supplying increasingly complex products to other sectors of the economy and playing an essential role in industrial value creation. Value creation in this industry has been relatively stable in recent

years in main producing countries like Germany, Japan, Korea and Italy (Figure 2.11). Nevertheless, the sector is undergoing profound transformations, characterised by an increasing product complexity, overreliance of firms on selling hardware rather than integrated solutions and external challenges such as rising material costs and price-eroding competition (McKinsey, 2021^[76]).

Figure 2.11. Value added contribution of the machinery and equipment sector

Value added embodied in global final demand for machinery and equipment n.e.c, by country, as a share of national value added, 2010 and 2020.

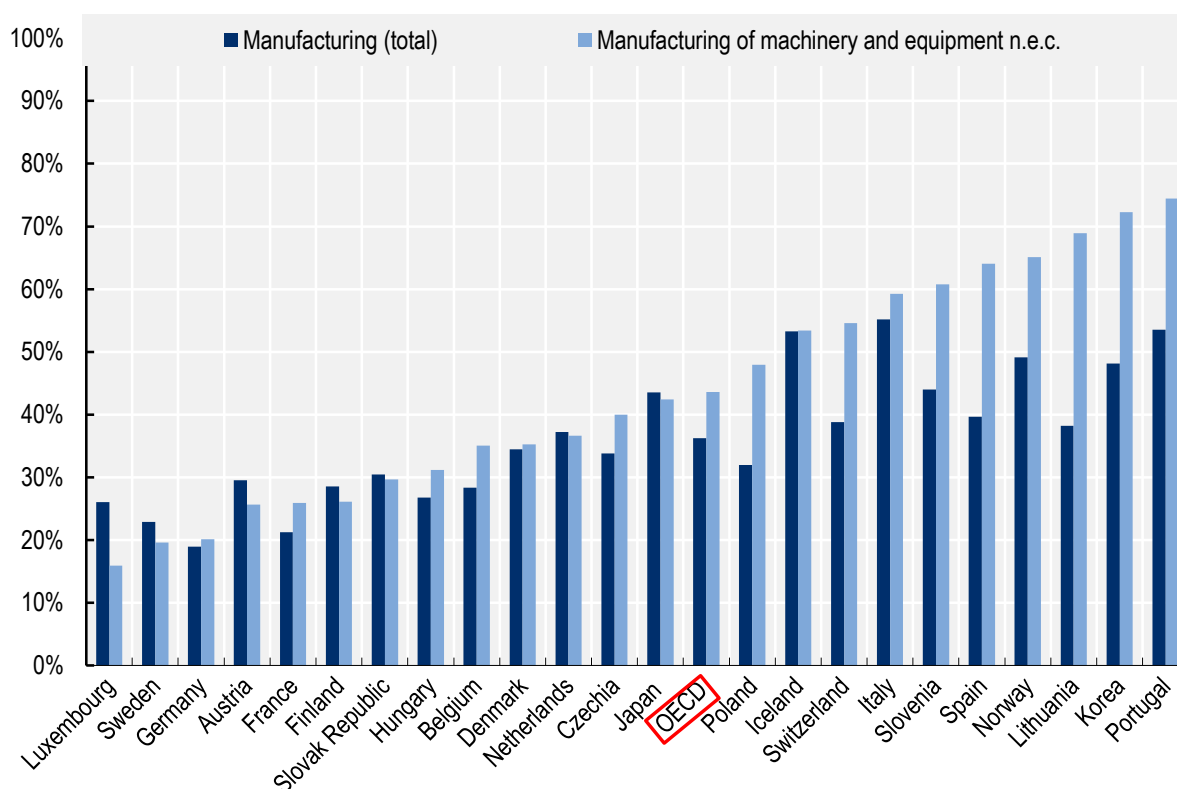


Note: For example, in Germany 3.7% of the total domestic value added is part of the global final demand machinery and equipment n.e.c.

Source: OECD, Trade in Value Added Database (TiVA), oe.cd/TiVA; TiVA indicators are derived from OECD's Inter-Country Input-Output (ICIO) tables.

SMEs play a vital role in the machinery and equipment manufacturing sector representing the vast majority of companies, accounting for a sizeable amount of turnover – around 44% across the OECD, higher than the SME contribution to the overall manufacturing sector. This SME share of industry turnover raises up to 60-75% in certain economies including Portugal, Korea, Lithuania, Spain, Italy, Slovenia, Norway (Figure 2.12). In particular, medium-sized companies play a crucial role in this sector, capturing large shares of turnover across the OECD.

Figure 2.12. SME share of turnover in manufacturing (total) versus manufacturing of machinery and equipment, 2022



Note: SME shares of turnover calculated with values for selected OECD countries, including for Korea (2020), Japan and Iceland (2021). SMEs defined as firms with 1-249 employees.

Source: OECD, Structural business statistics (SBS) by size class and economic activity (ISIC Rev. 4).

However, the SME share of turnover in the sector declined in recent years. Across OECD countries, the average share fell from around 50% in 2010, to 48% in 2015, to 44% in 2022⁷. The shift in turnover from SMEs to large companies suggests a widening gap between SMEs and large firms in terms of capabilities to adapt to ongoing economic transformations.

Transformative changes in the machinery and equipment sector

Digitalisation, automation, and connectivity

The process of digitalisation is heavily impacting the industry and SMEs operating therein. These impacts are evident in shifting products and customer demands, as well as changes in production processes (often referred to as *Smart Manufacturing*, Box 2.8) that increasingly integrate higher levels of automation and connectivity.

The construction machinery sub-industry provides an illustrative example of the increasing degree of automation and connectivity. Sensors and network communication are increasingly important, as they have become sufficiently cheap and small to be integrated into controller unit of future machines. Other complementary innovative products include construction robots, drones, and AI-based solutions to enable predictive maintenance of construction machines (Porsche Consulting, 2020^[77]). For many SMEs, this trend implies navigating a growing complexity in products, which demands a higher level of technological expertise.

This growing complexity in products aligns with another significant trend, similarly observed in the automotive sector: the servicification of products. Firms are slowly shifting from purely offering machine components to also providing complementary services such as repair and maintenance. This shift is particularly challenging for SMEs, as it requires them to transition from their core business of delivering hardware components to becoming facilitators of an ecosystem of machinery and equipment components (MRPeasy, 2022^[78]; Porsche Consulting, 2020^[77]).

The structural changes emerging from the shift in types of products can also be exemplified by machinery SMEs delivering intermediate products to the automotive industry. The decline in demand for traditional powertrain components may affect their core business but also attracts new entrants to the markets including new-battery electric-vehicle OEMs, mobility operators and logistic start-ups which all rely on different types of vehicles (cars, trucks, off-road equipment). Thus, machinery SMEs may be able to leverage their core capabilities, for example in assembly and coating, to produce similar products delivered to a new customer base (McKinsey, 2021^[76]).

Box 2.8. Smart Manufacturing (SM)

Smart Manufacturing can be defined as the integration of advanced technologies and data-driven processes to enhance efficiency, productivity, and flexibility in manufacturing operations. In the context of *Smart Manufacturing*, machines are equipped with electronic sensors to generate data which serve businesses in developing knowledge and improving communication across the firm (Taylor, Baron and Schmidt, 2015^[79]). To improve workflow, digitalised companies rely on modelling and simulation software. Industrial Internet of Things (IIoT) solutions enable them to gather machine performance data and remotely controlling equipment (MRPeasy, 2022^[78]). IIoT platforms facilitate efficient data transmission, storage, and analysis, leveraging cost-effective cloud solutions available today (Mittal et al., 2019^[80]).

The Smart Manufacturing market, whose technologies are increasingly more accessible to SMEs, is anticipated to grow annually by about 13% until 2030 (Forbes, 2023^[81]). A 2022 survey by SME (formerly the Society of Manufacturing Engineers) and CESMII (Smart Manufacturing Institute) indicates that over 75% of respondents from US manufacturing companies believe smart technology will enhance their competitiveness, but only about 50% are willing to invest in smart manufacturing initiatives (SME, 2022^[82]). This gap underscores that, despite the recognised advantages of smart technologies, manufacturers, especially small ones, are hesitant to allocate resources on opportunities in smart manufacturing.

New engineering methods reduce time and costs for prototyping and offer opportunities for new forms of collaboration

The changes driven by digitalisation processes of machinery manufacturers, such as the increasing demand for automated and connected equipment, also change the way products are designed. New machines and production processes can be modelled and simulated virtually. As opposed to previously longer cycles of prototyping, technologies in the area of virtual and augmented reality (VR/AR) as well as additive manufacturing (3D printing) may be used to reduce costs and shorten the product development cycle. In particular, advancements in 3D printing for the production of complex metal parts increasingly drive a shift from machining to additive manufacturing (MRPeasy, 2022^[78]). This shift allows for more rapid and cost-efficient prototyping because 3D printing enables firms to produce small batches without the traditional preparatory steps (i.e. production of a mold to prepare machine parts) (E-Plus-3D, 2022^[83]). As

SMEs in the sector precisely tend to produce smaller batch sizes of specialised products as compared to large firms, 3D printing offers SMEs a valuable tool to rapidly innovate their products.

Additionally, the growing adoption of technologies such as IoT and AI facilitates new forms of collaboration among companies. Examples of emerging IoT-powered platforms illustrate how such initiatives enable SMEs to exchange data, identify synergies, and enhance service delivery (Box 2.9).

Box 2.9. Case studies: Collaboration on IoT-platforms enable machinery and equipment SMEs to boost digitalisation and connectivity

Italian lift sector SMEs create IoT-powered platform to foster innovation and competitiveness

Challenge

Over the past years, the Italian lift industry has been under increasing pressure to digitalise along with fierce competition. The demand for modernised production and maintenance processes is spread across numerous SMEs, requiring effective communication among various players. Further, different types, provenance and age of components complicate interoperability between different lifts – ranging from mechanical elevators to cutting-edge lifts equipped with free Wi-Fi.

Solution

In 2013, 18 SMEs founded TRE-E consortium. Some of the founding companies are competitors in the market but had previously collaborated on developing advanced control systems. Further closer co-operation was driven by the objective to boost innovation to remain competitive. The TRE-E consortium runs the IoT-powered platform *Smart Lifts*. It established an IoT training centre and started to gather data on different lift types with the goal to pool and standardise data formats, to be able to manage lifts more efficiently. They set the goal to connect 40 000 lifts by implementing their technology via standardised data formats, such as IoT-sensors to generate administrative and historical data for service efficiency improvements (European Digital SME Alliance, 2021^[84]; OECD, 2022^[85]).

German Startup Oculavis GmbH leads the way in digitalisation production processes

The German Startup Oculavis is a software developer which has developed a handful of digital solution with the goal to increase process quality in production and create smart self-services for machinery and equipment manufacturers.

These tools include a software platform and augmented reality applications, information and visual support. Their connected worker solutions replace paper-based instructions with digital, interactive ones for setup processes and training. Further, the platform enables the maintenance and inspection of tickets directly at machines, link them with step-by-step guides, reports, and logs, and provide employees with crucial machinery knowledge (KfW, 2021^[86]; oculavis, n.d.^[87]).

Diversification of technologies required to adopt Smart Manufacturing poses significant challenges to SMEs

Machinery manufacturers that develop innovative technologies for other businesses often spearhead digitalisation. However, many of these leading firms are large, and a significant gap in digital adoption persists between machinery SMEs and large companies, which also reflects in a widening gap in turnover and labour productivity.

As highlighted by research on Korean firms, path dependencies in the adoption of new technologies may pose an additional barrier to SMEs. The research indicates that firms are more successful in adopting or

developing new technologies if they have already accumulated related technologies (Kim, Jun and Lee, 2023^[88]). Thus, given the currently lower level of technology adoption in smaller firms, they may face structural barriers to diversifying their technologies in the future. However, this technological diversification is crucial to meet the shifting product, and customer demands prevalent in the machinery and equipment manufacturing sector.

To capitalise on the growing opportunities in smart manufacturing, SMEs face significant challenges, including high investment costs and organisational changes. Currently, advanced solutions are mainly adopted by large firms. A 2018 study of 68 German manufacturing SMEs (36 of which are machinery manufacturers) highlights common challenges in adopting advanced solutions encompass the high costs of IT infrastructure, IT personnel and technical training (Mittal et al., 2019^[80]). Keeping up with modernising production processes requires significant investments, both in implementing advanced technologies and in developing the capabilities to effectively use the data these technologies generate. However, for many SMEs, the willingness of customers to pay does not match this increase in costs.

The increasing complexity of products and the shift towards automation and connectivity in production require higher skill levels in the machinery sector. SMEs face challenges in this regard, especially in acquiring and developing the digital skills required to adapt to the growing demand for digital solutions. The accelerated digitalisation of the sector has widened skill gaps between SMEs and large companies, as evidenced by the rapid increase in the demand for skills in automation, IoT and cybersecurity⁸ (OECD, 2022^[89]). Additionally, machinery companies face challenges in attracting and retaining employees with the necessary AI expertise (Bain & Company, 2024^[90]), which poses risks to their capacity to compete in the near future.

Resource efficiency, energy use and emissions reduction

The trend towards more low-carbon and resource-efficient production and consumption patterns is creating both opportunities and challenges for machinery and equipment manufacturers. The machinery sector plays a central role in enabling transitions across the economy, as its products are critical inputs for reducing emissions and improving resource efficiency in other industries. As a result, machinery producers are increasingly adapting their product portfolios to meet evolving demand. For instance, the expansion of renewable energy markets is increasing demand for components such as bearings, brakes, couplings and gearboxes used in wind turbines, with the global wind gearbox market projected to reach EUR 24-31 billion over the next decade. Similarly, decarbonisation efforts in hard-to-abate sectors such as cement rely on technologies that combine chemical processes with machinery components including electric drives, compressors, valves and control systems. This is contributing to the growth of specialised markets, such as that for CO₂ compressors, which is projected to exceed EUR 20 billion by the end of the decade (McKinsey & VDMA, 2022^[91]). While the growing markets for these types of solutions open opportunities for new revenue streams for startups and SMEs, it also comes with challenges to navigate increasingly complex technological and regulatory requirements.

At the same time, the overall machinery and equipment sector CO₂ emission footprint is marked by a relatively high share of scope 3 emissions, in particular those originated from sold products. A study on a sample of 38 machinery and equipment manufacturers in Germany, Switzerland, and Austria reveals relatively low shares of scope 1 and 2 emissions (5%), while the majority of emissions relate with the purchased services, namely raw materials and intermediates (25%) and use of sold products (65%) (Strategy&, 2022^[92]). For SMEs, this underscores the importance of working closely with suppliers to source lower-emission materials and components, while also designing products that are more energy-efficient, durable and easier to repair, reuse or recycle.

Reducing energy consumption also remains a key competitiveness challenge. Machinery manufacturing relies on energy-intensive processes such as forging, casting and machining, making firms particularly exposed to fluctuations in energy prices. In the European Union, the machinery sector accounted for

approximately 7% of final industrial energy consumption in 2022 (Eurostat, 2024^[93]). Rising energy costs have therefore placed additional pressure on many SMEs, reinforcing the need for investments in energy efficiency and process optimisation.

In this context, digital technologies can play an important enabling role. Advanced software solutions that track material flows, monitor equipment performance throughout its lifecycle and optimise maintenance schedules can help SMEs improve resource efficiency, reduce energy consumption and lower emissions. Such technologies can support emission reductions not only in firms' own operations (Scope 1 and 2 emissions) but also across the lifecycle of the products they manufacture and sell (Scope 3 emissions).

More broadly, the shift towards circular and resource-efficient business models offers new avenues for growth and diversification. Opportunities are emerging in areas such as remanufacturing, repair services, predictive maintenance and resource-efficient machinery solutions. However, realising these opportunities often requires substantial investments in new technologies, workforce skills and organisational capabilities, which can be particularly challenging for smaller firms.

Policy responses to global megatrends in the machinery and equipment sector

Policies in the broader manufacturing landscape often have impacts on the machinery sector, since this sector is closely interconnected with other industries, such as automotive and semiconductors. For instance, government initiatives aimed at boosting semiconductor production directly impact the machinery sector, which provides essential equipment, such as photolithography and wafer handling systems and equipment, which are critical for expanding domestic chip production capacity.

Acknowledging the wide-ranging nature and impact of policies targeting the manufacturing sector at large, the following section focuses on major strategic policies and machinery-specific legislation including R&D support programmes, some of which are specifically designed to support competitiveness of SMEs in the sector.

Strategic agendas and machinery-specific legislation

As outlined in the previous section, the significant transformation of the machinery sector is largely driven by the digitalisation, automation, and the increasing servicification of products. This shift in products and production processes has created a new ecosystem of components, with greater software integration and evolving demands for maintenance and repair. To support companies adapting to this, strategic initiatives have been launched across OECD countries over recent years. These include strategies that target the manufacturing sector at large such as the U.S. National Strategic Plan for Advanced Manufacturing, I-Korea 4.0, the EU Digital Strategy, or the German platform industry 4.0. These policy initiatives, largely aimed at boosting the digitalisation of the manufacturing sector, impact SMEs across various dimensions, operational (e.g., AI and IoT integration), financial (investments in new technologies), and strategic (market access).

Additionally, machinery-specific regulations, initially developed to ensure safe interactions between humans and machines, now consider evolving technologies, changing market conditions and the increasing integration of software components into machinery manufacturing. This is exemplified by the updated EU Machinery Regulation 2023/1230, which also aims to reduce administrative and compliance costs for SMEs through preferential conditions, such as reduced fees for the updated conformity assessment⁹ (Box 2.10).

Policy initiatives that aim at accelerating the low-carbon transformation of the industry, such as the *EU Green Deal Industrial Plan*, also have an impact on the machinery manufacturing sector, including SMEs, as the market for energy-efficient equipment and technologies expands (European Parliament, n.d.^[94]).

Major policy initiatives also emphasise the localisation of supply chains to enhance industrial resilience. The 2022 U.S. Inflation Reduction Act (IRA), for example, offered tax credits for domestically produced machinery components, with the aim to reduce reliance on foreign suppliers and shield supply chains from global disruptions. The machinery and equipment sector often operates through fragmented supply chains and is thus highly vulnerable to economic shocks at national or global level, like falling demand and lower prices during recessions (Allianz Trade, 2024^[95]).

Box 2.10. EU Machinery Regulation 2023/1230

Overview

The EU Machinery Regulation, updated in 2023, legally binding in all EU Member States by 2027, introduces several changes compared to the previous 2006/42/EC directive, in particular to address the integration of advanced technologies and software components in the machinery sector.

The 2023 EU Machinery Regulation introduces several key features to enhance product safety and compliance with modern technologies along with the other relevant regulations such as the EU Cyber Resilience Act. It broadens the definition of safety components to include physical, digital, and software elements, addressing emerging challenges posed by new digital technologies such as AI, IoT and robotics. Additionally, it establishes cybersecurity requirements to protect machinery from threats that could compromise safety functions, urging manufacturers to reassess their safety concepts. Finally, the regulation allows manufacturers to provide digital instructions and declarations, with a requirement to supply paper formats upon customer request.

SME-specific considerations

While the regulation applies broadly, the updated conformity assessment procedures are simplified for certain machinery types, reducing administrative burdens for smaller manufacturers. The new regulation also includes provisions for reduced fees for conformity assessments specifically aimed at SMEs. Finally, the regulation encourages the use of harmonised standards for machinery products, potentially facilitating easier paths to compliance to SMEs. However, as of 2024, details on the integration of harmonised standards and compliance for SMEs remain unclear.

Source: (EUROGIP/ European Trade Union Institute, 2023^[96]; PILZ, 2023^[97])

Financial instruments supporting machinery and equipment SMEs

Various financial instruments are available to support businesses in the machinery and equipment sector, including SMEs, in line with national and supra-national agendas for digital and low-carbon manufacturing. Although most instruments are not exclusively designed for SMEs, they are fully accessible to them. These instruments include tax incentives, loans or grants that help SMEs modernise equipment, innovate or receive targeted financial support for resource-efficiency measures or renewable energy generation. Some key examples include:

Leveraging funding from the Recovery and Resilience Facility (RRF), various EU governments have implemented support initiatives aimed at boosting energy efficiency and renewable energy generation in industries, including SMEs in the machinery and equipment sectors. For instance, under the industry decarbonisation component of its national recovery plan, Portugal has introduced targeted calls focused on energy-saving projects and renewable energy generation, striving to reach a large number of SMEs.

In Japan a Green Innovation Fund¹⁰ as well as the GX promotion strategy provide dedicated financial support for companies' low-carbon transition. The 2023 *GX promotion act* supports technological

advancements, including through GX economic transition bonds, carbon taxation, and a carbon trade market. Additionally, the *Ministry of Economy, Trade and Industry (METI)*'s "Initiatives for Ensuring the Stable Supply of Machine Tools and Industrial Robots" aim to ensure reliable supply of essential manufacturing equipment within the country to mitigate risks of supply chain disruptions. Alongside subsidies for large machinery companies, these initiatives aim to reinforce the competitiveness of the advanced machinery and equipment sector by promoting technological innovation, with a particular focus on strengthening SMEs (see country profile Japan, Machinery).

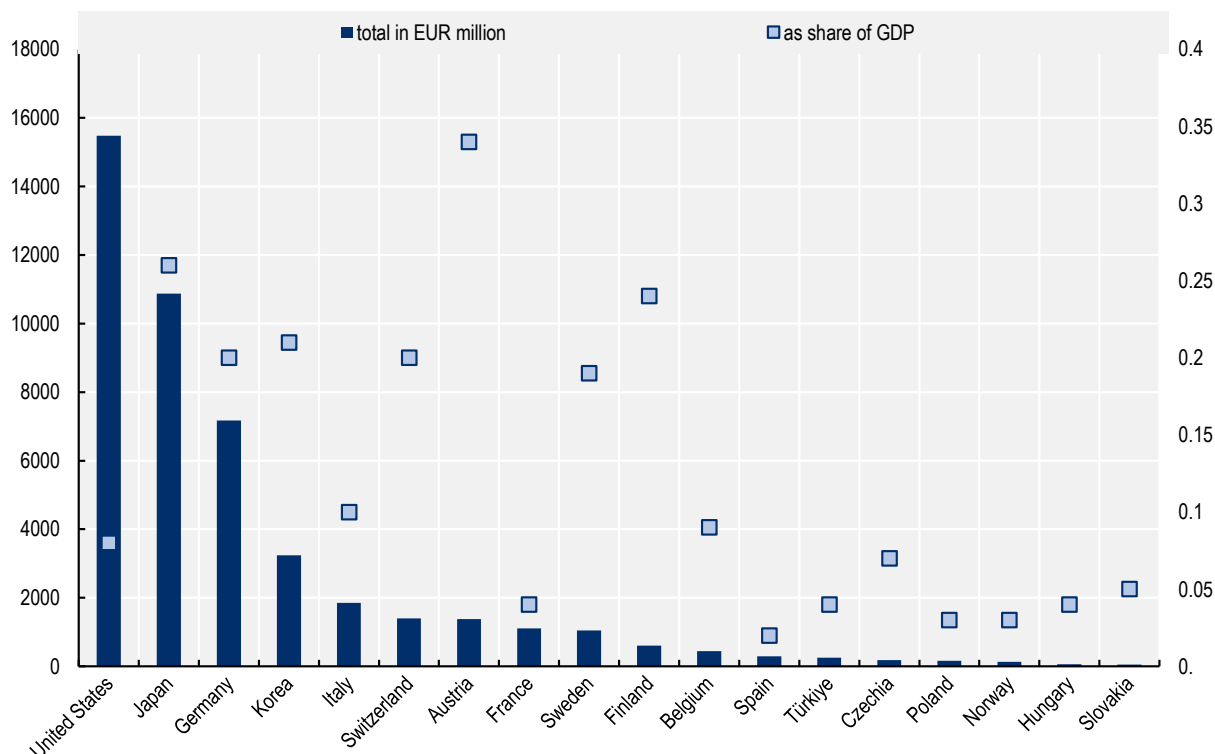
The 2022 U.S. IRA introduced tax incentives for producing domestically sourced components for the manufacture of low-carbon energy systems, along with an increase in R&D tax credits for small businesses. The provisions have been subject to policy changes since 2025, including modifications to several tax incentives. In its first two years, these IRA provisions were associated with a rise in investment, particularly in battery manufacturing (Rhodium Group/ MIT CEEPR, 2024^[98]). The expanded market for battery solutions presents opportunities for those machinery SMEs specialised in battery production equipment, including assembly lines, cell manufacturing machines, and testing equipment. Market opportunities for SMEs can also stem from increased demand for components and machines of other energy-system technologies, including solar, electrolyzers, and wind power.

R&D support and technology transfer to machinery and equipment SMEs

Following the OECD Taxonomy of Economic Activities based on R&D intensity (Galindo-Rueda and Verger, 2016^[99]), the machinery and equipment sector is classified as a medium- to high-R&D-intensive industry, reflecting its reliance on advanced technologies and continuous innovation. The expenditure on R&D (of both SMEs and large companies) is particularly high in certain OECD countries including the U.S., Japan and Germany, followed by Korea and Italy (Figure 2.13).

Governments typically encourage R&D through a combination of tax incentives, research grants and other support measures. Such interventions are particularly relevant for SMEs in the machinery sector, which must continuously innovate to keep pace with larger competitors while facing considerable obstacles to adopting new technologies. These include high capital investment requirements and growing demand for specialised skills to operate and integrate automated systems, robotics and AI-based solutions.

Figure 2.13. Business enterprise expenditure on R&D in manufacturing of machinery and equipment sector n.e.c. by country, 2021



Source: Eurostat, OECD. BERD by NACE Rev. 2 activity and source of funds, https://doi.org/10.2908/RD_E_BERDFUNDR2.

Several broad-based R&D support programmes are highly relevant to the machinery sector, particularly those promoting smart manufacturing, robotics and data-driven solutions. Alongside these, a number of smaller and more targeted initiatives are specifically designed to support SMEs in the machinery and equipment sector. For example, Germany's *SME-innovative: The Future of Value Creation* programme (Box 3.8) supports cutting-edge R&D projects tailored to the needs of SMEs in the sector. Given the significant costs associated with adopting advanced technologies and the specialised skills required to deploy them effectively, many R&D support programmes seek to improve SMEs' access to innovation funding while reducing administrative burdens. Common measures include simplified application procedures, more streamlined reporting requirements and faster feedback on funding decisions.

Examples of policy initiatives with relevance for SMEs in the machinery sector include the following:

- In Korea the *Smart Manufacturing Innovation Support Programme* under the *Manufacturing Innovation and DX Acceleration Strategy* offers R&D support, funding, and resources to assist SMEs in adopting advanced manufacturing technologies (covering from 30-100% of project costs). This includes support for smart factories, robotics and process automation and data infrastructure for SMEs to increase their competitiveness in the area of smart manufacturing (MSS, 2023^[100]).
- In France the challenge "Transfert Robotique", managed by the National Research Agency (ANR) and Bpifrance, aims to transfer practical robot solutions in key industries, supporting both SMEs and large companies through grants for R&D activities and investment in equipment and software (Bpifrance, 2024^[101]).
- In Germany the flagship initiative under the international Manufacturing-X initiative called *Factory-X* (Box 2.11) provides funding for R&D projects, led by a consortium of companies, to develop a

data ecosystem for factory equipment suppliers. The project includes a dedicated component for disseminating and transferring knowledge to the industry, particularly focusing on SMEs. SMEs actively participate in the R&D projects, and their access is facilitated through the development of easily deployable plug-and-play solutions.

A critical factor in ensuring that innovation reaches a broad range of firms, including SMEs, is the effective transfer of knowledge and technologies generated through R&D activities. However, despite many projects focusing on SME-oriented solutions, SMEs often have limited involvement in the resource-intensive development process. This disconnect can result in solutions that are not fully aligned with their specific needs. To address this challenge, initiatives like Germany's Manufacturing-X, including Factory-X, integrate SMEs into the development process and, additionally, include knowledge transfer components into the policy initiatives. A notable example is the "ScaleMX project", which allocated EUR 4 million under Manufacturing-X, to support networking and capacity-building activities within the innovation ecosystem, helping SMEs better adopt and benefit from smart manufacturing technologies.

Box 2.11. Germany's Factory-X (under Manufacturing-X)

Budget: EUR 70 million + additional budgets for knowledge transfer projects

Operated by: Federal Ministry for Economic Affairs and Energy (BMWE), Germany

Description:

Factory-X is the lighthouse project among the seven major Manufacturing-X projects aimed at establishing a cross-industry, open data ecosystem for the manufacturing sector. The initiative, led by the large companies *Siemens* and *SAP* in collaboration with 47 partners, establishes an open and collaborative data ecosystem for factory equipment suppliers and operators. The BMWE supports the initiative through different measures including non-repayable grants for R&D projects, the creation of knowledge transfer structures, and further support for the creation of interoperable data ecosystems (BMWE, 2023^[102]).

This project builds on concepts developed under the "Catena-X" project and the "Industry 4.0 platform", with an overall focus on connectivity and communication between machines and systems on the production floor. Thematically, the project is divided into 11 use cases centred around specific business applications. The use cases are designed to extend existing supply chain-oriented solutions (horizontal) by adding vertical integration, which directly connects shop floor operations (Factory-X, 2023^[103]).

Factory-X focuses on the development of solutions in R&D projects in the following areas:

- cross-manufacturer data consistency for engineering, equipment information, and condition;
- sustainability through carbon footprint and energy management, alongside digital solutions that support a circular economy;
- digital solutions for "as-a-Service" business models (e.g., marketplace/pay-per-part, remote control/monitoring);
- traceability of materials, data, and products across the entire supply chain;
- updates and changes for field devices.

In addition to the technical development of Factory-X, the consortium of companies involved also plays an important role in coordinating development activities across different Manufacturing-X projects and in building an international Manufacturing-X community (BMWE, 2024^[104]).

Skills initiatives and the role of local actors

The digital transformation of the machinery sector is increasing demand for a broad range of specialised skills, notably in automation, IoT, AI and cybersecurity. As discussed in the trends section of this chapter, SMEs face particular challenges in acquiring these capabilities and frequently trail larger firms in terms of digital skills and expertise. According to OECD work on the future of rural manufacturing, a digital skill gap is also visible between rural and urban areas, with only 23% of individuals in rural areas having basic or above digital skills, compared to 62% in urban areas across Europe in 2019 (OECD, 2023^[105]). This highlights the regional and local dimension of the skills gap, with the many machinery and equipment SMEs located in rural areas facing added challenges in attracting the digital talent necessary to transform their operations and adapt to the increasing complexity and diversification of machinery products.

While many skills initiatives and capacity-building activities are coordinated at the national or even supra-national level (e.g., the 2020 EU Pact for Skills), most incorporate a local dimension or are implemented through local trainers and institutions, such as regional labour offices and innovation agencies. These local actors play a critical role in needs-based design and effective implementation of programmes. Beyond trainings, events and seminars, many of these initiatives also offer networking opportunities, fostering collaboration and knowledge exchange among SMEs and industry experts. Examples of initiatives to upskill and connect manufacturing SMEs, particularly relevant to machinery SMEs, are the U.S. Manufacturing Extension Partnership (MEP) (Box 2.12) and the targeted German state policy programmes for the transformation of manufacturing SMEs (Box 3.11).

Box 2.12. Manufacturing Extension Partnership (MEP), United States

The U.S. *Manufacturing Extension Partnership (MEP)* is a programme administered by the U.S. Department of Commerce's National Institute of Standards and Technology (NIST). Initially authorised in 1988, its primary mission is to strengthen and empower small and medium-sized U.S. manufacturers through state-designated MEP Centers located across the U.S. and in Puerto Rico. The programme comprises nearly 1 400 trusted manufacturing advisors and experts at more than 450 MEP service locations.

MEP is a public-private partnership, designed from inception as a cost-share programme. Federal appropriations pay one-half, with the balance for each Center funded by state / local governments and/or private entities, plus client fees. Operating on a fee-for-service basis, MEP provides manufacturers with a range of services, including training and capacity building in advanced manufacturing technologies, business growth strategies and lean production practices. It also supports firms in the adoption of new technologies, such as Industry 4.0 solutions, and in strengthening their cybersecurity capabilities.

The MEP works in close collaboration with their partner *Manufacturing USA*, which operates at national level through 17 manufacturing innovation institutes and aims to advance future manufacturing capabilities through applied research and technology development within large scale R&D innovation projects, as well as dedicated training programmes. MEP supports the deployment and adoption of these technologies and business practices through MEP centres within states, primarily for manufacturing SMEs.

Source: <https://www.nist.gov/mep>; <https://www.manufacturingusa.com>; (Manufacturing USA, 2021^[106])

Concluding observations on SME support in the machinery sector

Over the past several years, major policy initiatives at the national, regional, and supra-national level have focused on the digitalisation of the manufacturing sector. At the heart of this transformation, the machinery and equipment industry is increasingly characterised by the integration of software components, automation, and a shift toward service-oriented business models.

While relatively few initiatives have directly targeted the machinery and equipment sector and its SMEs, relevant support has often been provided through broader R&D programmes and dedicated components within them. In parallel, industrial policy initiatives have sought to expand domestic manufacturing capabilities and strengthen strategic supply chains. Regulatory frameworks have also evolved to reflect technological change. The EU Machinery Regulation, for instance, recognises the growing integration of software and digital technologies in machinery products and seeks to establish a more proportionate and manageable compliance framework, particularly for SMEs.

Despite the availability of broad policy support for innovation and digital transformation, many SMEs in the machinery sector continue to face significant barriers to adoption. In particular, substantial gaps remain between SMEs and large firms in terms of digital capabilities, resources and access to data-driven technologies. As industrial data ecosystems become increasingly important, larger companies often play a dominant role, while many SMEs struggle to keep pace due to limited financial and technical capacities. This raises the risk that SMEs will be excluded from key digital networks and miss opportunities associated with the ongoing transformation of manufacturing.

These challenges are becoming more pronounced, as machinery products become more complex, compliance requirements evolve alongside rapid technological change. In this context, targeted R&D programmes, such as those implemented in Korea and Germany, play an important role in supporting SME competitiveness. Within these programmes, specific components are designed to transfer knowledge and facilitate SMEs' access to the developed data-driven solutions. Additionally, some targeted programmes are specifically designed to make R&D funding more accessible to SMEs, such as through fast feedback mechanisms that help streamline the process for small enterprises.

Nevertheless, sector-specific support for SMEs in the machinery sector remains relatively limited. A key challenge is the high cost of adopting advanced technologies and automating production processes, which often requires substantial investments in equipment, organisational change and workforce skills. To address these barriers, in many OECD countries local training, advisory and upskilling initiatives have been implemented. Some programmes also foster networking and collaboration opportunities, including cross-sector partnerships on issues such as data standardisation and interoperability, helping SMEs become more integrated into data and innovation ecosystems. Expanding these initiatives and improving SMEs' access to relevant training and funding opportunities will be critical to enhancing their long-term competitiveness and resilience in an increasingly complex machinery manufacturing environment.

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Notes

¹ At the Paris Motor Show in 2016, Dr. Dieter Zetsche, former CEO of Daimler AG and Head of Mercedes-Benz Cars, firstly introduced the concept of CASE presenting the company's strategy for the mobility of the future (Mercedes-Benz, 2024^[110]).

² This shift is associated with comparative advantages of selected regions in producing specific components. Due to the dominance of Asian manufacturers in battery cell production, a significant portion of the value creation for battery-electric vehicles has shifted from Europe to Asia. For example, in comparing the production of Volkswagen's traditional Golf VIII with the fully electric ID.3, about 20% of the European powertrain value creation has moved to Asia (e-mobil BW, 2023^[9]).

³ In Korea, there are middle-market enterprises between medium-sized and large enterprises. Middle-market enterprises are defined by the Act on the Promotion of Growth and Competitive Enhancement of Mid-sized Enterprises.

⁴ In 2024, the European Council adopted the Euro 7 regulation for emissions of substances like N₂O and CH₄. An interesting aspect is that the new regulation targets not only traditional internal combustion engine vehicles but also electric vehicles in case of particulate matter from brakes and tyres. Especially, the Euro 7 introduced minimum performance requirement for battery durability. The United States Environmental Protection Agency (EPA) also announced the reinforced emission standard for both passenger cars & trucks (light-duty) and commercial trucks & buses (heavy-duty) (U.S. EPA, 2024^[107]). However, EPA regulations and Euro 7 standards were relaxed from their original plans due to push-back from automobile manufacturers (Folk, 2024^[108]) (Reuters, 2024^[109]).

⁵ According to the fit for 55, emission targets for the period of 2020-2024 are 95g CO₂/km for passenger cars and 147g CO₂/km for vans, 55% CO₂ emission reductions for new cars and 50% for new vans from

2030 to 2034 compared to 2021 levels, and finally 100% CO2 emission reductions for both new cars and vans from 2035.

⁶ SEMICONDUCTORS: Information on Projects Funded to Strengthen U.S. Supply Chain, [GAO-26-107882](#). Published: 11 December, 2025.

⁷ The fall in share of turnover reflects a general trend observed in the manufacturing sector (OECD averages calculated for selected OECD countries presented in Figure 1.2.). Depending on data availability, the averages for 2010, 2015, and 2022 were calculated using data from years that deviated by 1-2 years for Japan, Korea, Luxembourg, Portugal, and Switzerland.

⁸ On average, automation and IoT skill demands are diffused up to 6 times faster than other skill demands in labour markets in selected Anglophone countries (Skills for the Digital Transition: Assessing recent trends using Big Data, (OECD, 2022^[89]))

⁹ A manufacturer can place a product on the EU market only when it meets all the applicable requirements. Therefore, the conformity assessment procedure is carried out before the product can be sold.

¹⁰ Budget of JPY 2 000 billion, including support for R&D projects and implementation of green technologies.

3

Country profiles

This chapter provides an overview of manufacturing trends and policies in France, Germany, Japan, Korea and the United States. It examines key developments in the manufacturing sector with a focus on three main policy priorities: digital transformation, the transition towards more energy-efficient and low-carbon production, and the strengthening of supply chain resilience. The chapter also assesses the readiness of SMEs to respond to these megatrends and reviews main policy and support measures designed to facilitate their transition. The analysis draws on country- and sector-specific evidence, complemented by insights from stakeholder interviews.

Methodological note

The five countries covered in the chapter were selected based on several criteria, including the size of their GDP, the relative weight of the manufacturing sector in the economy, and the level of competitiveness or specialisation in the manufacturing industry. Focus is thus placed on countries where the manufacturing sector accounts for a sizeable share of GDP. As part of this report, interviews were conducted with a diverse range of stakeholders to inform the country-specific and sectoral analyses. These stakeholders were selected based on their relevant expertise in the design, implementation, and impact of SME-relevant programmes, as well as their sector-specific knowledge, particularly regarding barriers faced by SMEs in adapting to ongoing megatrends. The stakeholder group included experts from industry associations, federal-level policymakers, regional innovation agencies, and academic researchers. The expert interviews helped to gather qualitative insights on the main challenges SMEs face, the support mechanisms they consider most effective, and areas where further action is needed.

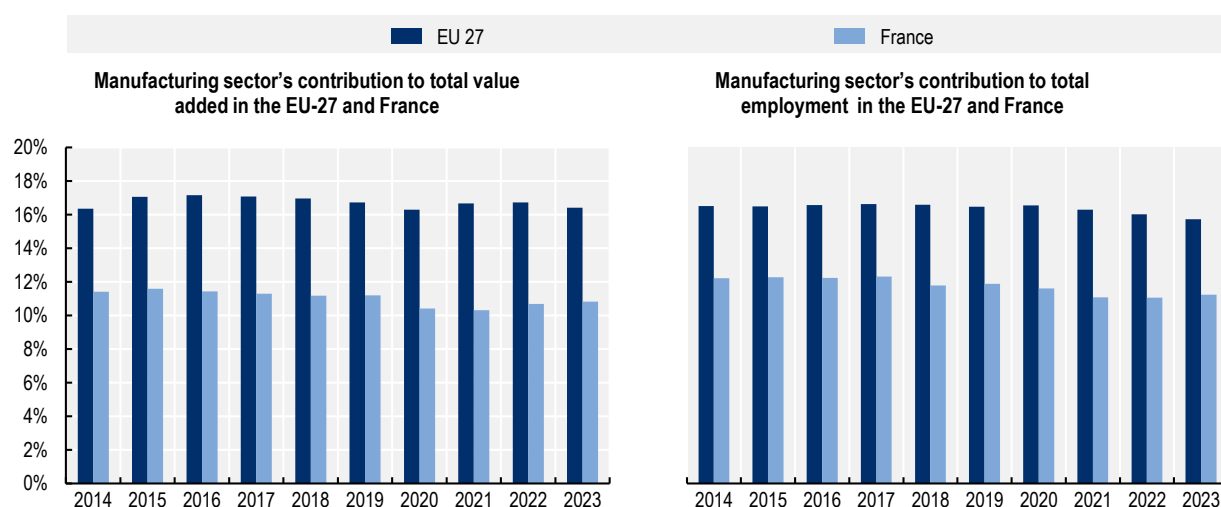
France

Introduction

SMEs are vital to the operations of the French manufacturing sector, which accounted for approximately 11% of the gross value added and 11% of total employment in 2023, below the EU average (Figure 3.1). Labour productivity in the French manufacturing sector experienced a sharp drop in 2020 (-8.5 percentage points with respect to 2019), more than double the average drop in productivity for this sector across EU27 countries (-4.2 pp). In 2021, labour productivity increased significantly (8pp with respect to 2020) but remained below the EU average increase (10.7pp) and in 2022 it decreased again by 2.8 percentage points while labour productivity increased on average in the sector across the EU (by 2.4 pp). Nevertheless, the French manufacturing sector has seen a positive trend in labour productivity in 2023, increasing by 1.2 pp with respect to 2022. This is a favourable comparison to the EU-wide decrease in productivity during the same period, by 1.7 pp (Figure 3.2).

Figure 3.1. Manufacturing sector's contribution to total value added and employment in the EU-27 and France

As a share of total gross value added generated in the EU-27, France and Germany respectively.

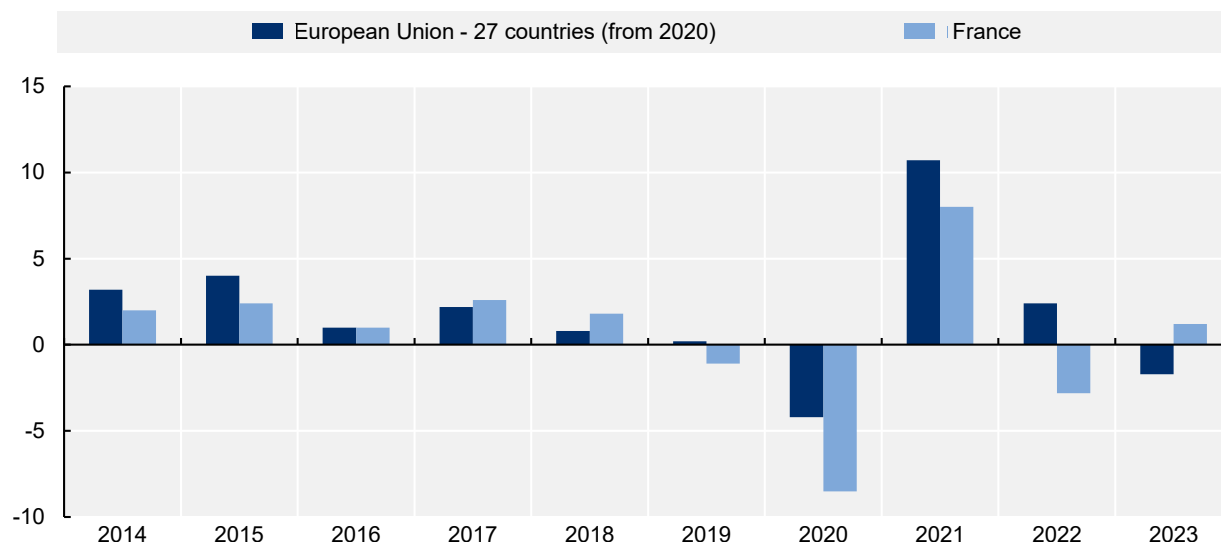


Note: Calculations by the authors.

Source: (Eurostat, 2024^[1])

Figure 3.2. Evolution of labour productivity in France and the EU-27 (2014-2023)

Percentage change on previous period



Source: (Eurostat, 2024^[2]).

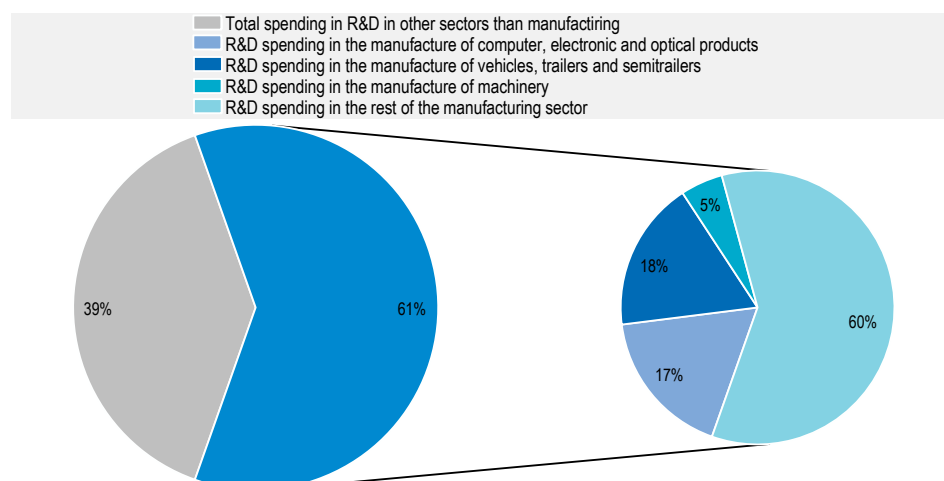
In France, the manufacturing sector accounts for 61% of total business enterprise R&D spending, a key indicator of innovation and competitiveness. Notably, 18% of this spending is concentrated in vehicle manufacturing, over 17% is allocated to the computer, electronics, and optical products sector, and 5% to machinery production (Figure 3.3). France is further experiencing a rising influx of requests for funding from industrial start-ups. In 2023, deep tech startups captured half of all funding for French Tech¹ (EUR 4.1 billion out of EUR 8.3 billion) with deep tech increasing its share by 38% despite an overall drop in funding (Bpi France, 2024^[3]; Fagot, 2024^[4]).

SMEs represent 99% of businesses in the French manufacturing sector, but challenges to their competitiveness – such as skills gaps – are increasing. A lack of workforce can lead to production constraints and heavily limit productivity and innovation, which rely on skilled workers. (World Economic Forum, 2023^[5]; World Economic Forum, 2023^[6]). High job vacancies especially affect small manufacturing businesses (1-9 employees). In 2023, on average, the job vacancy rate was 6.4% in companies with 1 to 9 employees against 2.6% in companies with 10 or more employees (Dares, 2024^[7]). A recent report by the General Inspectorate for Education, Sport and Research (IGESR) draws attention to an important mismatch between training offers and demand from companies, ascribing recruitment difficulties to low employment rates among vocationally trained individuals and their tendency to choose non-industrial careers, despite having industrial training (IGESR, 2023^[8]). To address the mismatch between the training on offer and the demand from companies, the IGESR recommends increasing collaboration between businesses and training programs, enhancing apprenticeships, improving the industry's image, and ensuring better alignment between education and job market demands, particularly at the technician level (IGESR, 2023^[8]).

Stakeholder interviews further highlighted the need to challenge stereotypes to increase female participation in the workforce. Women are indeed underrepresented in this sector, only accounting for 28,5% of the industrial workforce in 2022 (Secrétariat d'État chargé de l'égalité entre les hommes et les femmes, 2023^[9]). It must be noted however that a number of initiatives are already in place to boost the attractiveness of industrial professions and ensure a steady influx of talent, including the Industry Week ("Semaine de l'Industrie") coordinated by industry federations or the campaign "Industri'elles" to encourage more women to enter industry sectors.

Figure 3.3. Enterprise spending in R&D in manufacturing and within the manufacturing sector

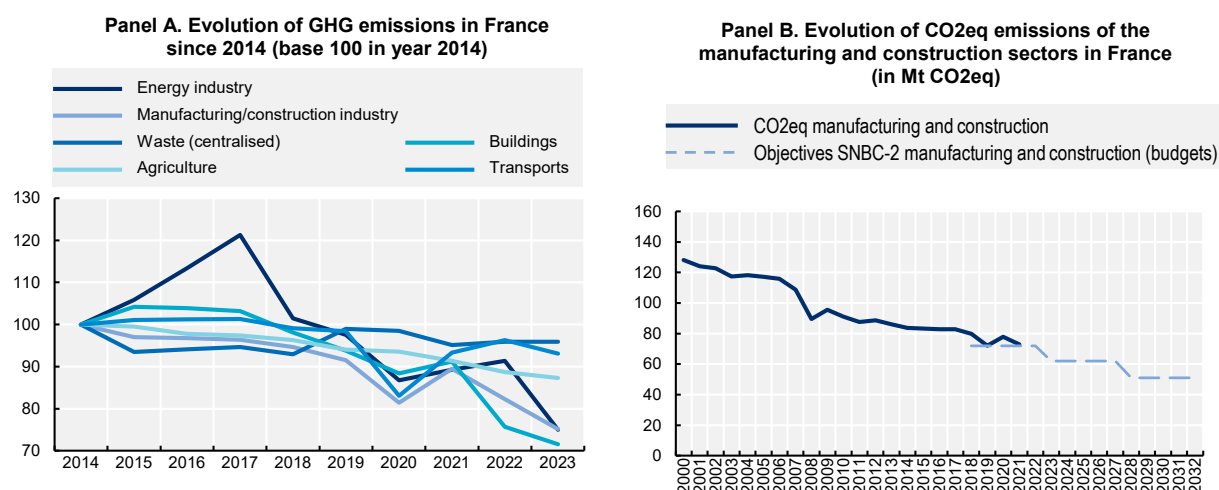
As a share of total enterprise spending in R&D and total spending in R&D in the manufacturing sector (2021)



Source: (Eurostat and OECD, 2024^[10])

In 2022, the manufacturing sector accounted for 18% of France's greenhouse gas (GHG) emissions. Emissions from this sector have decreased by 48% since 1990, significantly contributing to a 25% reduction in France's overall GHG emissions during the same period (France. CGDD SDES, 2023^[11]). Panel A of Figure 3.4 shows that manufacturing and construction sector emissions have decreased by 24 percentage points since 2014 (Citepa, 2024^[12]). Panel B further illustrates the emissions trajectory since 1990, highlighting how, despite this progress, current emissions remain slightly above the carbon budget for the manufacturing and construction sector defined in the National Low-Carbon Strategy (SNBC-2) providing guidance for implementing the transition to a low-carbon, circular and sustainable economy across sectors. In 2023, SMEs accounted for 20% of the French manufacturing sector's GHG emissions, below the EU average of 30% (OECD, 2023^[13]).

Figure 3.4. Evolution of GHG emissions in France since 2014



Note: SNBC-2 stands for "Stratégie Nationale Bas Carbone" or National Low-Carbon Strategy introduced by the Energy Transition for Green Growth Act (LTECV) and providing guidance for implementing the transition to a low-carbon, circular and sustainable economy across sectors. Source: (Citepa, 2024^[12])

Manufacturing SME readiness

Manufacturing SME sustainability readiness

Businesses in the manufacturing industry and the industrial sector as a whole are taking measures to reduce and decarbonise their energy consumption, but SMEs are lagging behind. A survey by Banque de France reveals that, in 2022, 90% of businesses in the industrial sector had adopted energy saving measures and 65% energy efficiency measures. In the manufacturing sector, 19% of surveyed businesses considered they were “very exposed to transition risks”, 6% considered they were exposed to physical risks and 56% to energy security risks. On average, surveyed businesses indicated they were planning to double their investments for the energy transition in the three following years. However, this was less the case for SMEs: while 65% of large companies indicated implementation of energy decarbonisation measures, less than 20% of surveyed SMEs did so (Banque de France, 2023^[14]). The 2024 SME climate survey by Bpifrance shows a slowdown in green investments, with only 28% of SMEs investing in 2023, down 14 percentage points from 2021, and just 26% planning future green investments. Nonetheless, the industrial sector stands out, with 57% of managers planning investments, including in green technologies, compared to lower activity in sectors like Construction and Commerce (Bpifrance Le Lab, 2024^[15]).

Recent studies show that French SMEs are increasingly aware of environmental challenges and proactively assessing their carbon emissions. According to a study by Bpifrance Le Lab, the share of SME leaders that are attentive to the environmental issues affecting their companies more than doubled since 2020, reaching 67% in 2023 against only 31% in 2020. Further, while many SMEs are exempt from the stringent regulatory obligations faced by larger companies, 35% of surveyed SMEs were proactively tracking their carbon emissions in 2023 (Bpifrance Le Lab, 2023^[16]). Nevertheless, many SMEs still face barriers to their environmental transformation, including limited financial resources, time and capacity to deal with complex administrative procedures and regulations.

SMEs remain constrained in their decarbonisation efforts due to limited resources and staffing capacities, which hinder their ability to manage complex administrative requirements, and to identify and implement decarbonisation investments. The Banque de France Survey reveals that while regulatory or tax uncertainty remained a major obstacle for large enterprises in the industrial sector in 2022 (42% compared to 26% of SME), the lack of skills to identify and implement investments represents a greater concern for SMEs (23% identifying this as a major obstacle) than for large companies (12%) (Banque de France, 2023^[14]). Further, SMEs are increasingly challenged by the growing complexity of administrative procedures. According to a survey by Bpifrance Le Lab, 76% of SMEs declare being constrained by complex administrative procedures, even more so than by limited access to financial resources (74%) or lack of time (67%). In addition, 66% mention cumbersome and sometimes contradictory standards for decarbonisation (Bpifrance Le Lab, 2023^[16]). Lacking the dedicated staff or technical capabilities of larger organisations, this can add to the already limited time that SMEs have to focus on technical issues, including environmental action (Bpifrance Le Lab, 2023^[16]; Bpifrance Le Lab, 2024^[17]).

While evolving non-financial reporting requirements offer SME manufacturers opportunities to improve sustainability and attract investment, they can also add pressure. New regulations are being introduced at the EU level to reach greening targets. While most SMEs are not yet mandated, they are still subject to reporting requirements through supply chains and financial institutions and are encouraged to prepare in anticipation of future regulatory changes, including to attract investments (OECD, 2022^[18]). For example, Socially Responsible Investment (SRI) funds have the same standards for SMEs as for larger businesses to provide labels, increasingly demanding non-financial data to assess climate-related risks (Label ISR, 2024^[19]; Bpifrance Le Lab, 2024^[17]). This however can also put additional strain on SME manufacturers lacking the resources of their larger counterparts. Further, audits are crucial to ensure the accuracy of sustainability reports that are voluntarily published by companies, to ensure credible actions are implemented and deter greenwashing (Bpifrance Le Lab, 2024^[17]).

A lack of certainty and predictability in financial support frameworks can deter decarbonisation investments by French SMEs. Steadfast public commitment to decarbonising industry is also instrumental for SME manufacturers to engage in long term and substantial decarbonisation investments. When the France 2030 programme was initially launched in October 2021, EUR 5.6 billion were earmarked for the decarbonation of industry. However, during a reprogramming exercise of the investment plan in October 2023, the budget for industry decarbonisation was reduced by over EUR 1 billion resulting in EUR 4 billion being allocated to this purpose (Sénat, 2024^[20]). This instability can deter decarbonisation investments by SMEs. In fact, the Bpifrance Le Lab survey revealed that 70% of surveyed SMEs perceived decarbonisation investments as a short-term competitive disadvantage.

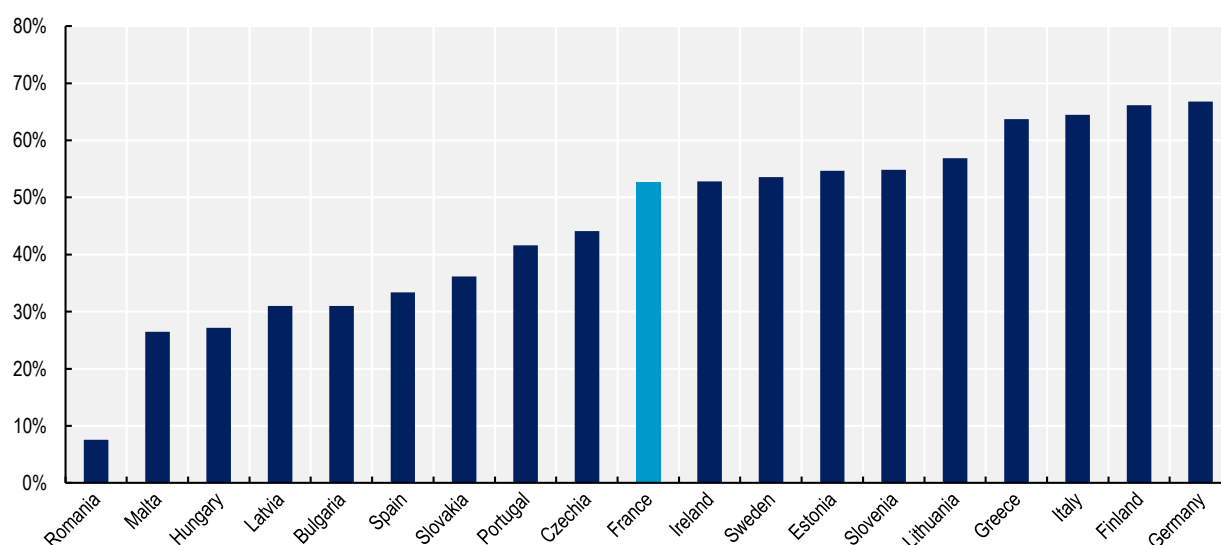
Manufacturing SME digital readiness

The adoption of basic and advanced digital solutions by French enterprises is below the EU average and the digitalisation of French SMEs remains an area with notable potential for further development. In 2023, 52% of French SMEs had “*basic level of digital intensity*”, against 57.7% on average in the European Union (European Commission, 2024^[21]). The adoption of cloud solutions by French enterprises is also significantly below the EU average, respectively standing at 22.9% and 38.9%. As for the adoption of AI, 5.9% of French enterprises had adopted AI applications in 2023, against 8% in the EU (European Commission, 2024^[21]). Bridging this digital gap can support the manufacturing sector’s transition towards more efficient and sustainable production processes. The installation of sensors and other digital tools, for example, enables SMEs across sectors to engage in energy optimisation strategies (OECD, 2023^[22]).

France also experiences a lag in the automation and robotisation of its industry with respect to other EU countries. According to the International Federation of Robotics (IFR) the robot density per 1 000 employees in the manufacturing sector stood at 180 in France in 2022, below the EU average of 208 (IFR, 2023^[23]). Encouraging the adoption of robotics by SMEs can have important impacts on their competitiveness, production at lower cost and enabling them to compete more effectively with large groups (bpifrance, 2024^[24]). Further, stakeholder interviews for this study highlighted that, in the case of SMEs lagging behind in the digital transition, incremental improvements are often more desirable than attempting a direct leap to the most advanced stages of digital transformation. This is primarily due to resource constraints, limited digital capabilities, and the need to align new technologies with existing operations and workforce skills. A phased approach can help mitigate risk and build internal confidence, enabling firms to advance their digital transformation more effectively.

There are fewer innovative SMEs in France than in other EU countries, while 53% of French industrial SMEs were considered to be innovation-active in 2022, this share is considerably higher in a number of EU countries as can be seen in Figure 3.5, including Germany (67%) or Italy (64%). This includes innovation in products and production processes. A recent survey by the European Union Intellectual Property Office reveals that the share of SMEs holding Intellectual Property Rights in France is lower (47%) than in other EU countries, including Italy (57%) and Spain (58%). The survey also indicates that, in France, SMEs that are IPR owners more frequently introduce innovations that are novel to their market or the world (25% of SME IPR owners) than non-IPR owners (18%) (EUIPO, 2022^[25]).

Figure 3.5. Share of innovation-active SMEs across selected EU countries



Note: An innovation-active firm is one that has had innovation activities during the period under review, including those with ongoing and abandoned activities (Eurostat, 2023^[26]).

Source: (Eurostat, 2022^[27])

Manufacturing SMEs in the face of supply chain disruptions

Since 2020, SMEs in the manufacturing sector have been increasingly facing supply chain disruptions, but recent findings suggest most are addressing these challenges. In 2020-2021, shortage of semiconductors had a strong impact on French automotive and tech sectors, particularly SMEs. While large corporations could secure their supplies through established relationships and financial resources, many SMEs struggled to navigate these disruptions (Madelaine, 2021^[28]). Since 2020, 31% of SMEs reported having been confronted with supply chain disruptions according to an SME survey by Bpifrance Le Lab. Nevertheless, the same survey shows that 61% of SME managers that declared being affected by supply chain disruptions, have taken measures to address this. Most effective measures include increasing stocks and diversifying suppliers, with respectively 78% and 72% of surveyed SME managers indicating they contributed to mitigating disruptions. Surveyed businesses also report the effectiveness of resorting to suppliers that are geographically closer, with 50% considering this strategy effective in reducing their supply difficulties (Bpifrance Le Lab, 2024^[29]).

Suppliers in the automotive sector have been under increased pressure first with the Covid-19 crisis and then due to semiconductor shortages. While car manufacturers have managed such pressures by raising prices, suppliers are struggling more, especially those hit by the rapid shift towards electrification, which diminishes the demand for traditional components like casting and stamping used in internal combustion engine vehicles (Euroactiv, 2024^[30]). Caught between rising material costs and demands from carmakers, automotive suppliers are currently facing workforce reductions and plant closures (Fay, 2024^[31]). Stakeholders interviewed noted that concerted efforts beyond crisis periods, such as the Covid-19 pandemic or the semiconductor crisis, lack continuity. Carmakers are placing excessive pressure on suppliers, which weakens them. Promoting longer-term relationships with suppliers could strengthen the supply chain.

Finally, it is crucial to recognise that the resilience of supply chains depends on overarching industrial strategies at both national and European levels, including robust monitoring initiatives. Leading to an incipient shift toward regionalisation to mitigate future disruptions at the EU level, the "European Chips

Act" aims to bolster regional tech sovereignty by 2030, addressing geopolitical tensions and rising logistics costs. At the national level, the France 2030 strategy emphasises industrial sovereignty and securing strategic materials to limit supply chain disruptions. Further, the French Observatory of Mineral Resources for Industrial Sectors (OFREMI) brings together the expertise of France's leading players in the analysis of strategic metals value chains, with the goal of ensuring better coordination and foresight in managing critical resources for industrial sectors. For example, by performing critical stress tests across the industry to ensure preparedness and strength against potential disruptions, in an effort to provide systemic support to enhance supply chain resilience (OFREMI, 2022^[32]).

Government policy (automotive, machinery and electronics)

France 2030

In 2021 the government launched the France 2030 5-year investment plan to support the development of innovative technologies, sustainable transformation and industrial competitiveness. Representing a total investment of EUR 54 billion to be spent in 5 years – including EUR 20 billion from the 4th “Investments for the Future” programme – 50% of the plan's expenditure should be allocated to purposes contributing to decarbonising the economy and 50% to supporting emerging players driving innovation (Site officiel du Gouvernement, 2021^[33]).

SMEs are indicated as key beneficiaries of the investment plan – in line with broader government efforts to support industrial SMEs – along with start-ups and mid-sized companies². Efforts in this field include the draft legislation “Projet de loi de simplification de la vie économique”³ or Simplification Law, which aims to reduce the administrative burden on businesses, particularly SMEs, and to streamline various administrative processes. The law aligns public participation, consultation and investigation for environmental authorisations in order to speed up administrative investigation procedures, preventing delays caused by the environmental authority's potential objections (Gouvernement, 2024^[34]). Importantly, the law intends to ease industrial and infrastructure projects, like data centres and renewable energy installations. The proposed legislation has been reviewed by the Senate; however, its vote was postponed due to the dissolution of the National Assembly (Direction de l'information légale et administrative, 2024^[35]). This is in line with efforts at the EU level to cut red tape, including the “Better Regulation Guidelines” aiming to rationalise reporting requirements. However, diverse stakeholders highlight the need to improve impact assessments and promote the “SME test” to ensure that regulations are fair and manageable for SMEs, as well as scaling up SME capacity building initiatives and giving SMEs access to affordable sustainability reporting professionals (SMEunited, 2023^[36]).

There are complementary efforts to decarbonise the industrial sector outside the scope of the France 2030 plan. These include the Green Industry Act or “Loi Industrie Verte”, approved by the government in October 2023 with the goal of accelerating the country's reindustrialisation and turning France into a European green industry leader (see Box 3.1). Other examples include the Energy Saving Certificates (“Certificats d'Économie d'Énergie”) programmes by the environmental agency ADEME. The “PACTE Industrie” initiative is for instance designed to support industrial companies in their transition to energy efficiency and low-carbon operations through tailored training and advisory services. Financial assistance covers 40% to 80% of training costs and 60% to 70% for studies and coaching. The programme also includes incentives for implementing Energy Management Systems (EMS) and supports companies as they establish comprehensive energy efficiency and carbon reduction strategies (ADEME, 2023^[37]).

Box 3.1. The Green Industry Act (“Loi Industrie verte”)

The measures put in place by the Green Industry Act should bring about a reduction of 41 million tonnes of CO₂eq by 2030 – equivalent to a 1% reduction in France’s overall emissions and accelerate the mobilisation of public and private capital for the transition, bolstering the creation of green jobs within the industry sector (Ministère de l’Économie des Finances et de la Souveraineté Industrielle et Numérique, 2023^[38]).

The law foresees leveraging funds collected from life insurance and retirement savings plans to further finance the decarbonisation of SMEs. The law identifies a growing interest among French savers to invest in projects that support the ecological transition and outlines several measures to meet this demand including (Légifrance, 2023^[39]) :

- A climate savings plan for young people to finance climate-related projects.
- The creation of a Green Industry Label to identify companies and projects that support decarbonisation to channel green investment.
- Simple labelling for green investments through straightforward labels that make these opportunities more transparent and reliable.
- Development of European Long Term Investment Funds (ETILF 2) and green private equity as part of financial products such as life insurance and retirement savings, encouraging private investment by insurance policy holders and investors in green industries.

The law also aims to facilitate the establishment of industrial complexes, with a goal to halve the timeframe for setting up factories through increased speed of administrative procedures. Projects of “major national interest”, determined by decree, now benefit from simplified procedures.

Additionally, it favours more environmentally virtuous operators for public procurement, with the possibility of excluding operators who do not meet their obligations at the European (CSRD) or national level (publication of GHG emissions assessment report and transition plan). The law makes the integration of environmental criteria in public procurement contracts compulsory since July 2024 (instead of August 2026) for key decarbonisation products (electric cars, heat pumps, etc.) (Ministère de l’Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2024^[40]). Finally, companies benefiting from public aid for the ecological and energy transition from the State and its operators will have to measure their environmental impact, via a GHG emissions assessment with a simplified procedure for medium-sized companies employing between 50 and 500 employees.

As part of the Green Industry Act, the government introduced in March 2024 a tax credit, to support companies in the financing of key industrial projects in the energy transition. The key beneficiaries of the Green Industry Tax Credit (C3IV) are manufacturers of batteries, wind power, solar panels and heat pumps, all of which contain **semiconductors**. This tax credit supports the entire production chain of these sectors, ranging from the production of **essential equipment and components** to the production or valorisation of critical raw materials. It is expected to generate EUR 23 billion in investment and the creation of 40 000 direct jobs by 2030. It should also make it possible to reduce emissions by 35 million tonnes of CO₂. In March, 20 applications for approval had been submitted, covering the four sectors concerned, for a total investment amount of 1.8 billion EUR (Ministère de l’Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2024^[41]).

Electronics

Securing the access to strategic materials and components is recognised as a key condition to achieving the objectives of the France 2030 investment plan. This is particularly the case in strategic areas such as electronics, robotics and intelligent machines, as well as the development of national software solutions in the fields of artificial intelligence, cybersecurity, cloud computing and quantum computing. In the field of electronics, the plan acknowledges the strategic importance of semiconductors, particularly in light of the recent shortages which paralysed the automotive industry. In this context, the plan allocated EUR 5 billion to the production of electronic components and aims to double chip production in France by 2028, expected to generate investments of around EUR 18 billion in the country. Efforts to boost production of semiconductors have already started, with the launch of a new factory in Crolles in 2023 (Box 3.2).

Box 3.2. The Crolles semiconductor factory

In 2023 a new semiconductor components factory started production in Crolles, a city in the Grenoble region. This was the result of a partnership between two private sector companies (GlobalFoundries and STMicroelectronics) for a total investment of EUR 7.5 billion with EUR 2.9 billion invested by the State within the framework of the France 2030 investment plan.

The factory focuses on the production of energy-efficient high-performance components for key European industrial sectors – including the automotive sector but also telecommunications and aerospace among others – adding nearly 6% of new production capacity across Europe by 2028 and contributing to easing supply tensions.

Source: (Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2023^[42])

Further, in June 2023, the European Commission approved 12 projects by French enterprises within the framework of the Important Projects of Common European Interest (IPCEI) in the field of microelectronics and connectivity. These projects will mobilise EUR 7 billion to create about ten factories in the electronics industry supply chain and are expected to create more than 2 500 jobs. These projects also target specific applications of microelectronics in multiple sectors, including the telecommunications and the automotive sector. It will also support researchers, SMEs and start-ups through financing and partnerships with research centres and key ecosystem players (Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2023^[43]).

In addition to production targets, France is also committed to investing in research and development in the electronics industry and increasing electronics training capacity. R&D efforts are particularly focused on the development of thin-etched 10 nanometre Fully Depleted Silicon on Insulator (FD-SOI) semiconductors in collaboration with the French Atomic Energy Commission (CEA) (Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2023^[42]). This technology is four times more powerful than the current technology and consumes four times less energy. Overall, the strategy establishes that 800 million should be devoted to supporting R&D in the electronics industry and a dedicated support scheme for innovative start-ups, SMEs and mid-sized companies should be created. Finally, the strategy allocates EUR 50 million to skills capacity building to support skills requirements throughout the industry (Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2022^[44]).

Automotive sector

The France 2030 investment plan earmarks EUR 5 billion for the transport sector, including a sub-objective of producing about 2 million electric and hybrid vehicles by 2030 (Ministère de l'Économie, des Finances

et de la Souveraineté Industrielle et Numérique, 2023^[45]). In October 2023, 1 million electric vehicles had already been secured (Gouvernement, 2023^[46]).

In order to support the automotive sector as it undergoes key transformations, the strategy aims to support R&D, the production of vehicles and components in France and to support businesses, in particular subcontractors, employees and regions (Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2023^[47]). In reaction to the stricter regulation on CO₂ emissions for new cars and vans adopted by the EU Council in March 2023, which currently bans the sale of new combustion engine cars in the European market from 2035 (Council of the European Union, 2023^[48]), the strategy foresees the implementation of a targeted support mechanism for upstream SMEs in the automotive supply chain, particularly exposed to sustainable transformation and digitalisation megatrends.

To achieve the goals set out in the France 2030 strategy for the automotive industry, the government presented the 2024-2027 strategic contract for the automotive sector. The contract includes measures to promote the development of affordable, competitive, connected and decarbonised mobility offerings, the development of the circular economy and the decarbonisation of the fleet as well as structuring an electric battery industry (Conseil Nationale de l'Industrie, 2024^[49]). Further, the contract suggests efforts to enhance the co-operation of stakeholders along the supply chain, as it highlights that the government will act as a guarantor of good relations between contractors and suppliers, and that exchanges between public authorities and contractors will be strengthened through regular high-level meetings (Conseil Nationale de l'Industrie, 2024^[49]).

Box 3.3. France 2030: targeted support for SMEs in the automotive sector

The France 2030 strategy includes several targeted supports for SMEs in the automotive industry in partnership with key stakeholders:

An accelerator programme for upstream companies in the automotive industry: Accélérateur automobile

This accelerator programme consists of a 2-year support programme in collaboration with Bpi France and the Automotive Platform (PFA), representing 4 000 enterprises in the automotive sector, including manufacturers, equipment suppliers, subcontractors, and mobility players. Eligible upstream companies in the automotive industry should have a turnover of more than EUR 10 million, over 10 employees and at least 40% of their activity in the automotive sector. In addition to tailored consulting services, the support includes trainings and workshop opportunities by HEC on topics like strategy, energy transition, financing, governance, and leadership. Additionally, there are industry-specific meetings for networking and knowledge sharing. 66% of the cost of the programme is financed by the government with EUR 33 000 remaining to be paid by beneficiaries in instalments (Bpi France, 2024^[50]).

The Steering Committee for Automobile and Mobility Research “CORAM 2024” call for projects

The Steering Committee for Automobile and Mobility Research was first launched in 2020 to fund projects in line with the automotive sector's strategic goals and focusing on developing clean vehicles and improving the sector's environmental performance (Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2020^[51]). The CORAM 2024 call for projects, operated by Bpifrance, in line with the France 2030 strategy, offers financial supports for projects in the automotive sector with a focus on six priority areas, including the production of zero-emissions vehicles as well as connected and automated mobility. Eligible projects must exceed EUR 1 million for SMEs and mid-sized companies, and EUR 4 million for large enterprises and are evaluated on innovation, environmental impact, socio-economic benefits, and financial viability. The support includes a combination of grants and recoverable advances, structured according to EU state aid regulations (Bpi

France, 2024^[52]). Since 2020, this programme has supported 60 projects with EUR 393 million for EUR 1.2 billion of investments (Conseil Nationale de l'Industrie, 2024^[49]).

Support for investment projects to produce the vehicles of tomorrow and their components.

A new call for projects to support automotive investment in 2024 will support projects to industrialise components dedicated to the vehicles of tomorrow and to modernise the industrial facilities of subcontractors. With an overall budget of EUR 900 million between 2023 and 2026, the support is addressed to companies of all sizes working on initiatives in key areas of automotive innovation. It includes developing and assembling future vehicles, producing essential components and equipment, creating infrastructure for electric and hydrogen vehicle refuelling, diversifying automotive subcontractors, and improving the environmental performance of production processes and sites. Projects must align with these strategic goals to be eligible for support (Bpi France, 2023^[53]). In 2023, the 49 winners had invested EUR 577 million and received public support of near EUR 107 million. The 2024 edition resulted in 68 new investment projects that will receive EUR 210 million in aid. Between 2023 and 2024, 33% of selected projects are attributed to SMEs, supported with EUR 60 million for about EUR 160 million of productive investments. An additional 20% of selected projects are attributable to mid-sized companies, having received EUR 66 million for more than EUR 310 million of productive investments (Conseil Nationale de l'Industrie, 2024^[49]).

Support for skills: the “Compétences et Métiers d’Avenir” initiative

This initiative supports training for key roles in the sector's energy transition, with EUR 67 million in public funds allocated to seven projects, for a total investment of over EUR 120 million. These projects focus on reskilling workers for digital and ecological roles, particularly in battery and hydrogen technologies. Additionally, the "Rebond industriel" initiative, with a budget of EUR 100 million until 2026 (Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2023^[54]), aims to support employment in regions heavily impacted by industry changes, ensuring future job prospects.

Source : (Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2023^[47])

Machinery sector

The France 2030 strategy also allocates EUR 800 million to support the emergence of Industry 4.0 projects and strengthening France's supply of equipment for the industry of the future (Site officiel du Gouvernement, 2021^[33]). The strategy has a strong focus on robotics for the industry sector:

- The "Transfert Robotique" challenge under France 2030 was launched in 2023 and aims to accelerate the transfer of research results into practical robotic solutions for key industries (both in large enterprises and SMEs), supporting the development and integration of robotics in sectors critical to the future of industry. This initiative seeks to identify and implement the most suitable technological components for operational constraints across various sectors, without discriminating by industry or technology type. Eligible projects include a wide range of robotics and intelligent machines, from drones to industrial robots. The challenge consists of two phases, managed by the National Research Agency (ANR) and Bpifrance, with substantial funding opportunities. Phase 1 focuses on preliminary feasibility studies, with grants between EUR 50 000 and EUR 100 000, while Phase 2 supports more advanced projects with budgets between EUR 2 million and EUR 10 million. The deadline for applications was in May 2024, with the total project duration can extend up to 40 months (ANR, 2023^[55]; Ministère de l'Enseignement Supérieur et de la Recherche, 2023^[56]).
- Bpi France launched a call for projects in 2023 to support the development of high-value-added robotic and industrial equipment sectors. It targets emerging markets or strategic areas critical to

energy and ecological transitions. Eligible projects should involve significant R&D, software, and production equipment investments, aiming to surpass current technological standards while addressing market demand and contributing to economic, social, and environmental goals. The call, open until June 2025, includes amendments to encourage participation from small businesses – by reducing the minimum requirements that a company must meet to qualify for participation – and emphasises ecological transition and AI integration. Funding will consist of grants and recoverable advances (Bpi France, 2023^[57]; Ministère de l'Enseignement Supérieur et de la Recherche, 2023^[56]).

The regional dimension of the France 2030 investment plan

The France 2030 investment plan also includes a strong regional dimension. The regionalised component of the France 2030 strategy focuses on four key areas: accelerating the emergence of innovative companies through innovation projects; fostering sustainable industrial collaborations via collaborative R&D projects that bring together multiple partners, including SMEs; enhancing the competitiveness of strategic sectors through sector-specific projects by providing shared production and R&D resources; and supporting businesses in adapting to economic and organisational changes through Professional Training Projects, which focus on skill development for new professions in partnership with training providers. Examples of supports put in place in the Normandy region are further described in Box 3.4.

Regional programs, which often involve state-regional co-financing, are instrumental to aid SMEs as they are often able to provide more tailored support. They complement national initiatives, which are often thematically focused, and can cater to less advanced technological SMEs by offering a more accessible pathway to innovation. This territorial dimension is also reflected in the implementation of France 2030. Within the component of France 2030 supported by French public sector investment bank Bpifrance – one of the four operators of the investment strategy along with the National Research Agency (ANR), the Ecological Transition Agency (Ademe) and the Deposits and Consignments Fund (CDC) – 26% of the aid had been directed to SMEs two years after the launch of the investment strategy. Excluding notified major projects, SMEs accounted for 52% of planned aid, while 12% was intended for research laboratories within the framework of the European Research Area. Finally, 75% of the EUR 12.4 billion in aid approved by the France 2030 Ministerial Operational Steering Committee, was for projects outside the Paris Region, with a strong focus on innovation and low-carbon transition (Bpifrance, 2022^[58]).

Box 3.4. The regional dimension of France 2030: the example of Normandy

The sector specific component of the regional France 2030 Normandy investment plan

Jointly funded by the State and the Normandy Region and implemented by Bpifrance, the supports align with the strategic priorities outlined in regional development plans as well as the regional climate plan.

The "Improvement and Transformation of Sectors" initiative

The initiative is designed to boost the competitiveness and innovation of strategic regional industries, including electronics, automotive, and logistics sectors. It provides financial aid in the form of both grants (50%) and repayable advances (50%), with total aid ranging between EUR 250 000 and EUR 2 000 000 per project. Projects must have eligible expenses exceeding EUR 500 000 and funding can cover up to 50% of these costs, depending on the project's specifics, risk level, and innovation potential.

Priority is given to projects that support the regional economic transition, particularly those involving shared industrial units, collaborative technical skill development, or the establishment of mutual technological platforms. Projects should demonstrate a clear contribution to structuring a strategic regional sector, involving multiple SMEs or mid-sized companies, and should aim for financial

independence from public support in the long term. The initiative is open continuously from February 7, 2023, until available funds are exhausted.

The "Projets d'Innovation" initiative

The initiative supports innovation-driven projects by SMEs and mid-sized enterprises (ETIs). It offers funding between EUR 75 000 and EUR 500 000 (up to 50% of eligible expenses) for projects in two stages: feasibility and development/pre-industrialisation. Eligible costs include personnel, equipment, subcontracting, and operational expenses (DRAAF Normandie, 2023^[59]).

The "Projets i-Démo Régionalisés" initiative

This initiative supports collaborative research and development projects to boost innovation, growth, and competitiveness in the region. This call for projects is open to consortia consisting of at least two companies (including one SME or ETI) and a research partner, with the aim of aligning with Normandy's strategic priorities. The programme finances projects with eligible expenditures between EUR 1 million and EUR 4 million, covering personnel, equipment, subcontracting, and operational costs. Funding is provided as grants, with up to 60% for businesses and up to 100% for research institutions. The initiative prioritises projects in sectors such as energy, cybersecurity, and health (DRAAF Normandie, 2023^[59]).

Source : (Préfet de la Région Normandie, 2023^[60]; La Préfecture et les Services de l'État en Région, Normandie, 2023^[61])

Table 3.1. Summary of analysed policies in France

Investment Plan Name	Specific Initiative if applicable	Managing Entity or Organisation	Scope of Implementation	Policy Instrument	Target Group	Allocated Budget	Addressed Megatrend
France 2030	N/A	Le Secrétariat général pour l'investissement (SGPI)	National	Investment Plan	Industrial sector	EUR 54 billion in 5 years (2021-2026)	Digital, Low-carbon transition, and Value Chains
Green Industry Act ("Loi Industrie Verte")	Green Industry Tax Credit (C3IV)	Direction Générale des Entreprises (DGE)	National	Tax credit	Manufacturers of batteries, wind power, solar panels and heat pumps	EUR 3.7 billion (2024-2030)	Low-carbon transition, Value Chain
Certificats d'Économie d'Énergie	PACTE Industrie	ADEME	National	Training and advisory services	Industrial Sector	EUR 49 million (2023-2026)	Low-carbon transition
Second IPCEI ME/CT	N/A	Consortium of companies	National	State aid ⁴	Microelectronics sector	Projects by the 12 selected French companies should mobilise EUR 7 billion in total investment	Digital, Value Chains
France 2030	The Crolles semiconductor factory	Le Secrétariat général pour l'investissement (SGPI)	National	Public-private investment	Microelectronics, Automotive, Telecommunications and Aerospace sectors	Private investment: EUR 4.6 billion	Digital, Low-carbon transition and Value Chains

		GlobalFoundries				Public investment: EUR 2.9 billion	
		STMicroelectronics					
Automotive Strategic Contract	N/A	Conseil National de l'Industrie	National	Grants and recoverable advances	Automotive sector	Not specified	Digital, Low-carbon transition and Value Chains
France 2030	"Accélérateur automobile"	Bpifrance Plateforme Automobile (PFA)	National	Consulting services and trainings	SMEs in the automotive sector	Not specified	
France 2030	CORAM (automobile)	Bpifrance	National	Grants and recoverable advances	SMEs in the automotive sector	EUR 91 million committed to 11 projects	Digital, Low-carbon transition and Value Chains
France 2030	Support for investment projects to produce the vehicles of tomorrow and their components.	Bpifrance	National	Grants and recoverable advances	Automotive Sector	Not specified	Digital, Low-carbon transition and Value Chains
France 2030	The "Compétences et Métiers d'Avenir" initiative	Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique	National	Grants	N/A	EUR 2 billion in 5 years	Digital, Low-carbon transition, and Value Chains
France 2030	The "Transfert Robotique" challenge	ANR and Bpifrance	National	Grants	N/A	Not specified	Digital
France 2030	Appel à projets : "Offre de robots et machines intelligentes d'excellence"	Bpifrance	National	Grants and recoverable advances	High-value-added robotic and industrial equipment sectors.	Not specified	Digital,
France 2030 (Normandy)	1. Innovation projects 2. Improvement and Transformation of Sectors project 3. R&D collaborative projects	Bpifrance	Regional (Normandy region)	1. Grants and repayable advances 2. Grants and repayable advances 3. Subsidy	Electronics, automotive, and logistics sectors	EUR 50.77 million	Low-carbon transition, Digital
France 2030	"Rebond industriel"	1. Banque des territoires 2. Bpifrance	Regional	1. Engineering support 2. Subsidies and repayable advances	Transport sector	100 million until 2026	Digital, Low-carbon transition

Note: This table provides an example of the policies researched by the OECD for this project and does not offer a comprehensive overview of the country's policies in the manufacturing sector.

Source: OECD analysis based on desk research. (Ministère de l'Économie, des Finances et de la Souveraineté Industrielle et Numérique, 2023^[62]). (Bloom Legal, 2024^[63]). (ADEME, 2023^[64]). (DRAAF Normandie, 2023^[59])

Conclusion

Policies within the framework of the France 2030 investment plan, fit into a two-pronged approach: the national top-down strategy and a bottom-up approach tailored to local innovative projects, proactively reaching out to SMEs. Efforts to establish a cohesive strategy linking national and regional policies have been highlighted as successful in improving SME access to funding and tailoring supports to SME needs, especially in the automotive sector. The France 2030 Investment Strategy addresses a wide spectrum of industries and includes targeted supports for the automotive, semiconductors and machinery sectors.

Supports financed by the France 2030 investment programmes focus both on skills development and technology adoption, crucial for adapting to the rapidly evolving industrial landscape. Initiatives like “Compétences et Métiers d’Avenir”, the “Accélérateur Automobile,” or the PACTE Industrie, which offer trainings and/or consulting services, play a key role, alongside existing support for technology adoption (e.g., “Transfert Robotique,” “Appel à projets: Offre de robots et machines intelligentes d’excellence,” and “Support for investment projects to produce the vehicles of tomorrow and their components”). Investing in education and reskilling for industry-specific roles is particularly relevant to reduce the manufacturing sector’s job vacancy rate and increasing the attractiveness of industrial professions.

Stakeholder interviews highlighted that strengthening financial incentives, raising awareness, and simplifying access to existing resources could further enhance the effectiveness of these public initiatives. This is particularly important for decarbonisation investments in the manufacturing sector. SMEs, in particular, often face greater financial constraints than larger companies and therefore rely on a stable and accessible regulatory framework, as well as predictable funding at both national and EU levels, to plan and invest for the long term, especially given the manufacturing sector’s typically long investment cycles.

Efforts are being put in place at the national level to cut red tape, including the Simplification Law which contributes to diminishing administrative burdens. Finally, stakeholder interviews suggest that enhancing coordination between French industrial players – particularly in the automotive sector – and supporting a cohesive industrial policy are key, with efforts in this direction being suggested in the latest automotive sector strategic contract.

Germany

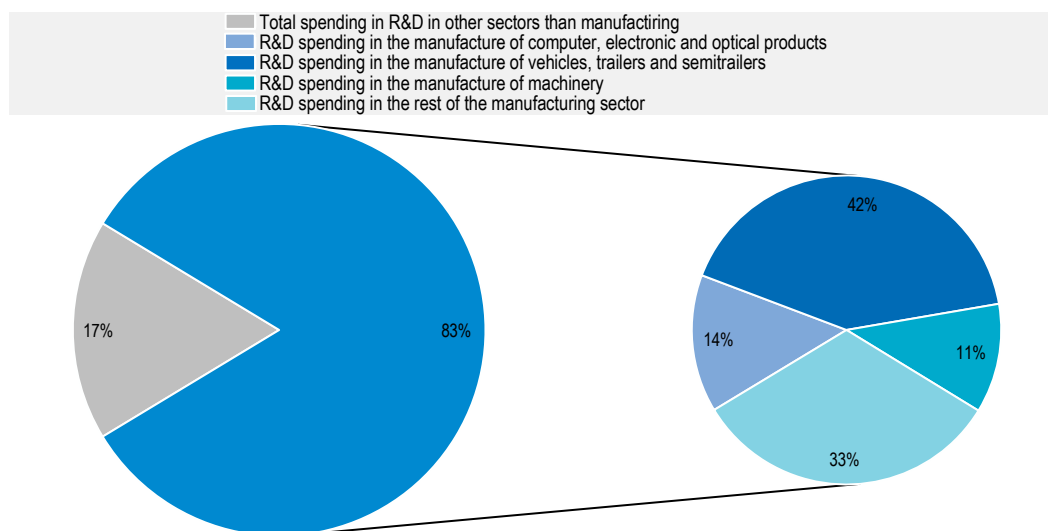
Introduction

The manufacturing sector represents the backbone of the German economy, contributing 20.4% of gross value added in 2023, a higher share than in other large EU economies (Destatis, 2024^[62]). In 2024 manufacturing directly employed nearly 9% of the German workforce. More broadly, around 15 million of Germany's 45 million jobs are directly or indirectly linked to the manufacturing sector (BMW, 2023^[63]; Eurostat, 2024^[64]). Germany also exhibits a strong manufacturing orientation in terms of R&D expenditure, a key indicator of future competitiveness (see Figure 3.6), underscoring the sector's strategic importance and ongoing efforts to maintain Germany's technological and industrial leadership.

SMEs account for the vast majority of firms in the manufacturing sector, representing on average 95% of enterprises across the three selected manufacturing industries. They play a crucial role in Germany's key industrial value chains, particularly in the automotive and machinery sectors. While larger enterprises generate the majority of turnover, SMEs remain important contributors to employment, accounting for around 38% of the manufacturing workforce in 2021 and serve as key suppliers and sources of innovation. Especially the automotive industry, with its extensive network of manufacturers, SME suppliers, dealers, and workshops, represents a key driver of economic activity in Germany, in particular in selected regions. The automotive supplier industry plays a key role in employment, with around 270 000 employees (in October 2023) as well as being a driver of technological advancements (Oliver Wyman, 2023^[65]). Besides the automotive sector, Germany is a leading global exporter in machinery and equipment, accounting for 16% of global trade in 2021, with many SMEs generating sizeable shares of turnover (20% in the machinery and equipment sector in 2022).

Figure 3.6. R&D spending in Germany is distinctly focused on manufacturing

Shares of R&D spending, Germany, 2021



Source: Enterprise statistics by size class, BERD by NACE Rev.2 activity (from 2021 onwards) and source of funds [rd_e_berdfundr2_custom_12710480]:

https://ec.europa.eu/eurostat/databrowser/view/sbs_sc_ovw_custom_12499124/default/table?lang=en

Manufacturing SME readiness

Digital transformation

The widening gap in digital adoption between SMEs and large firms as well as the manufacturing sector's shift of focus in value creation from mechanics to electronic systems and from hardware to software puts German SMEs under pressure. A 2018 survey of 68 German manufacturing SMEs highlights common challenges to the adoption of new technologies for manufacturing SMEs. These include high costs related to IT infrastructure, personnel, and technical training (Mittal et al., 2019^[66]). Further, challenges consist in the need to improve the flow of data between the stakeholders involved in the value creation process in the automotive industry (VDA, 2020^[67]).

In the face of those challenges, many SMEs have undertaken significant investments to adapt to ongoing transformations. In recent years there has been a significant increase in the number of German SMEs investing in digitalisation projects, particularly in the manufacturing sector. This trend is especially pronounced among SMEs in the R&D-intensive manufacturing sector, where 54% are engaged in digitalisation efforts between 2020 and 2022, compared to less than 37% of SMEs in the service sector. Overall, spending on digitalisation projects in German SMEs reached an all-time high in 2021, with EUR 23 billion invested (KfW, 2024^[68]).

Economic shocks and supply chain disruptions

The German economy was significantly impacted by high-energy prices following Russia's war of aggression against Ukraine. Energy-intensive industries that compete internationally (such as manufacturing) were affected, with a 10% decrease of production in 2022, followed by a recovery driven by the German price-cap policy and subsequently falling energy prices (OECD, 2023^[69]; OECD, 2023^[70]). However, rising energy costs are compounding other challenges to the competitiveness of German businesses, including SMEs, such as administrative and regulatory burdens and shortage of skilled workers in an ageing society. This is exemplified by Volkswagen's 2024 consideration of factory closures in Germany, an unprecedented step in the company's history⁵.

In the German automotive industry, specific challenges for suppliers consist in stagnating volumes of car sales, with unparallel fluctuations due to factors such as the semiconductor crisis, and high energy prices and inflation (Oliver Wyman, 2023^[65]). This is coupled with a shift in production to Asia and North America, where the German economy is expected to lose a substantial portion of its car production – among other factors due to high energy costs, and regulatory requirements. For example, parts of the electric vehicles value chain have shifted to Asia, reflecting the region's dominance in battery cell production. For example, comparing the two Mercedes models S-Class (internal combustion engine) and EQS (electric drive), 40% of production has moved to from Europe to Asia (e-mobil BW, 2023^[71]).

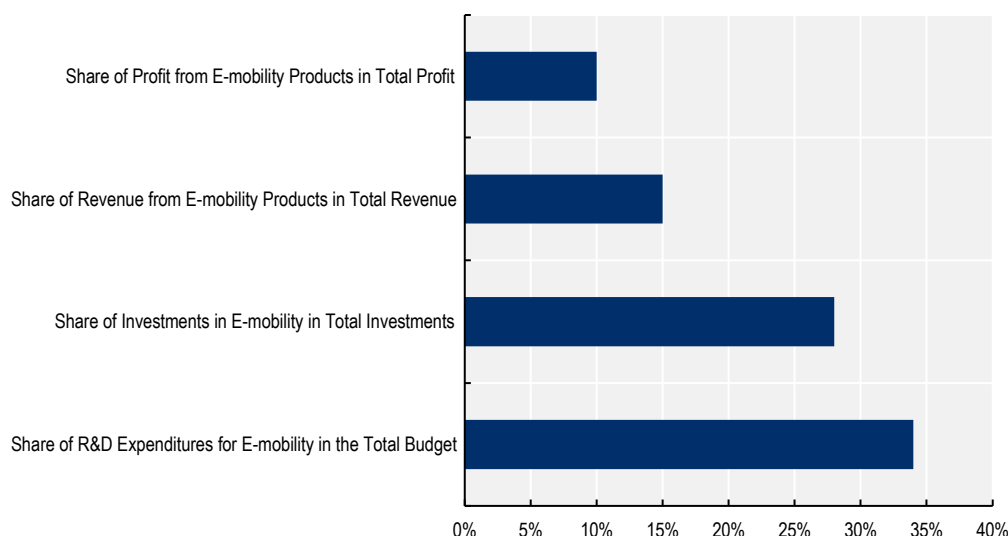
Low-carbon transition and electrification

In the German manufacturing sector, SMEs contribute around 23% of GHG emissions (OECD, 2023^[13]) while facing significant barriers to resource efficiency and circularity, including a lack of specialised skills and infrastructure. A main challenge consists in adjusting to the evolving demands of OEMs (e.g., switch to lighter materials to reduce OEMs' emissions in production). Interestingly, the most impacted firms in the automotive sector are not exclusively the suppliers of component for internal combustion engine, but also those SMEs that manufacture parts of the auto interior, such as seats or flooring (Sarkar, 2018^[72]). The reason is the pricing pressure on OEMs (e.g., through needs to invest in technologies and business model transformations), which cascades down the supply chain, compelling OEMs and Tier-1 suppliers to demand lower-cost components, such as seats made from less expensive materials. According to a 2023 survey of 74 automotive car suppliers in Germany, the transition from internal combustion engines to

alternative drive technologies is consuming significant financial and personal resources. This shift is resulting in higher current costs than the benefits provided (see Figure 3.7). Additionally, the sudden political shift to phase out the environmental bonus for the purchase of EV at the end of 2023 may have temporarily decreased supplier's share of profits from e-mobility products.

Figure 3.7. Automotive supplier's Shares of E-mobility in Selected Financial Metrics

Germany, 2023



Note: The results contain survey responses from 73 German suppliers from October/ November 2023 (25% with annual revenues below EUR 100 million and 33% between EUR 100-500 million)

Source: VDA-survey in (Oliver Wyman, 2023^[65]).

The machinery sector plays a key role in decarbonisation efforts, as machinery and plant engineering enable decarbonisation through its products. A survey among 57 German machinery manufacturers⁶ reveals that the vast majority considers the sustainability transformation as chance to maintain or expand their business, with 31% expecting to broaden their product portfolio with green products (McKinsey & VDMA, 2022^[73]). Customers of machinery manufacturers are already demanding features like reduced energy consumption (32%) and minimised product losses (30%)⁷, pushing machinery companies to adapt.

Government policy (automotive, machinery and electronics)

The government support landscape for equipping SMEs to undergo transformative changes in the manufacturing sector is complex, as it comprises several initiatives from varying funding sources, including the EU, national programmes, and federal state programmes⁸. The present section provides an overview of key policies aimed at future competitiveness, resilience and adaptation to digitalisation and greening, starting with major flagship programmes at national level. Some of the analysed national policies also include broader support programmes that are promoted through regional partners such as state agencies. The following section presents targeted state level policies which offer manufacturing SMEs a concrete point of contact and multiple support services to undergo transformations.

The primary focus of the policies analysed is the leading automotive sector. However, SMEs from machinery and equipment, and electronics sectors are also impacted by these policy measures, either due to their direct involvement in the automotive supply chain, or through benefitting from the evolution of policy

support over time, which, at both national and regional levels, extended to a variety of sectors beyond the automotive industry (see “*Manufacturing-X*” in Box 3.7 and “*Transformationslotse Bayern*” in Box 3.11).

In the electronics sector, SME-specific programmes are limited, but, innovative SME may benefit from other main policy initiatives, such as R&D projects under the European *IPCEI⁹ project on Microelectronics and communication technologies* (including government funding of EUR 4 billion), as well EUR 5 billion funding to support the new European Semiconductor Manufacturing Company in Dresden (BMW, 2023^[74]; DW, 2024^[75]). Also, major policy initiatives targeting the automotive sector such as the measures to increase supply and demand of EVs (Box 3.5) have a significant impact on market conditions, requiring many SMEs to adjust to these evolving conditions to remain competitive.

Box 3.5. The German Climate Protection Act and major policy measures to foster the EV uptake (automotive)

Commitment: With the amendment of the Climate Protection Act, the federal government has tightened existing climate protection regulations and set the goal of becoming net greenhouse gas neutral by 2045. As an interim target, Germany's greenhouse gas emissions are to be reduced by 65% compared to 1990 levels by 2030.

Policies: The transport sector experiences the transformation to more environmentally friendly vehicles as a gradual process, with a variety of policies driving the shift from traditional internal combustion engine-centred value chains to EV production. Key policies to increase the supply and demand of EVs, as to reach a total number of 15 million fully electric vehicles on the streets by 2030, include:

- Increasingly strict **EU fleet-wide CO2 emission targets** (95g CO2/km for cars from 2021, and a 100% emission reduction from 2035 onwards),
- **Environmental bonus for purchase of EVs** (2016-2023, up to EUR 4500 EUR per car; EU 10 billion spent for the purchase of 2.1 million EVs), support halted by government's decision following the ruling of the Federal Constitutional Court on the Climate and Transformation Fund,
- **Vehicle tax relief** for battery electric vehicles (BEV) until 2031,
- Other measures include the development of **charging infrastructure, free parking in inner cities, measures to use bus lanes** (with the 2015 Electric Mobility Act acting as basis for granting EVs those special privileges in public traffic areas).

Impacts of policies and shifting market conditions:

When compared to selected European countries, in 2022, 31% of newly registered passenger vehicles in Germany were EVs – both Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV) – placing the country ahead of France (22%) and the UK (24%), but behind the Netherlands (34%), Sweden (56%), and Norway (88%) (e-mobil BW, 2023^[71]). In December 2022, the combined share of BEV and PHEV reached its peak with 51% of market share of newly registered vehicles – potentially due to the reduced environmental bonus from beginning of 2023 that led customers to bring forward planned purchases in 2022 (now-gmbh, 2023^[76]). While the share of BEV had increased to 31% in August 2023, the share of new BEV registration went down to less than 14% one year later in August 2024, following the final halt of environmental bonus for the purchase of EVs in autumn 2023 (ADAC, 2024^[77]). The subsequent decrease in demand and forecasts for EVs led to uncertainty among investors in the EV market and a backlash for supplier companies, including SMEs, investing in production of EV components.

Targeted investment subsidies and R&D activities (digitalisation/ low-carbon transition/ resilience)

As part of the 2020 **economic stimulus package (KoPa 35c)**, the German government launched a bonus programme earmarking EUR 1 billion to enhance the competitiveness of vehicle manufacturers and supplier industry by promoting future investments. The overarching SME-relevant funding framework is called “**forward-looking investments by vehicle manufacturers and their suppliers**”, implemented by the Federal Ministry for Economic Affairs and Energy (BMWE) and co-financed by the EU. Within this framework, Module a1 (investment promotion programme) and a2 (R&D programme) are designed to enhance the productivity and resilience of vehicle manufacturers and component producers.

Investment grants to modernise production (automotive)

The funding programme “**modernisation of production**” (**Module a1**), running from 2021-2023, aimed to support the transformation of the automotive industry via the promotion of investments in new manufacturing facilities, processes and industry 4.0-capable manufacturing infrastructure. This explicitly included investments to help SMEs in the component supplier industry introduce digital and sustainable manufacturing processes, supporting them against the consequences of the COVID-19 pandemic. 50% of applications were submitted by SMEs. 496 projects were supported – each project covering from 10-50% of the investment costs –amounting to an overall volume of EUR 190 million. Eligible costs included investments in production facilities such as acquisition of machinery, equipment and software, as well as complementary investments for building competencies such as consulting services and employee training.

R&D support and transfer: Digitalisation of supply chains in the industry (automotive, machinery, electronics)

Module a2 “Digitalisation of vehicle manufacturers and the supplier industry” of the funding framework supports collaborative R&D projects defined by the automotive industry. The support specifically targets innovative, data-driven production processes and the implementation of Industry 4.0 approaches within the complex value creation systems of vehicle manufacturers and the supplier industry. The funded projects are led and driven by companies from the automotive and supplier industry, with a strong involvement of SMEs whose participation is explicitly encouraged. The solutions, which aim to be developed through application-oriented, collaborative projects cover the following areas:

- Development of digital manufacturing concepts beyond traditional assembly line and cycle operation,
- Establishment of connected value creation processes increasing transparency and resilience of the production system against disruption – and allowing comprehensive data analysis along the supply chain,
- Development of holistic and collaborative, cooperative business models and processes in digital ecosystems,
- Implementation of Digital Twins which fully map product life cycles and thereby contribute to ecologically sustainable production.

With the targets set, the programme supports the National Industrial strategy 2030 to strengthen new technologies as well as objectives such as knowledge and technology transfer, which are anchored in the government’s High-Tech Strategy 2025. Moreover, the programme is embedded in the “Transformation Dialogue for the Automotive Industry” and the “Industry 4.0 Platform”, supported by the Federal Ministry for Economic Affairs and Energy (BMWE) and the Federal Ministry of Research, Technology and Space (BMFT) (BMWE, 2024^[78]).

Until the end of 2023, 37 collaborative projects have started working (363 subprojects) with a total funding of EUR 690 million, of which EUR 351 million is state funding. Project partners led by one major industrial company involved OEMs, supplier and technology companies (12 vehicle manufacturers, 11 Tier-1

suppliers, 14 Tier-2 suppliers, 7 Tier-n suppliers, 192 equipment/ technology companies). The first and flagship project **Catena-X** was running from 2021-2024 (see Box 3.6).

Box 3.6. Catena-X (Automotive sector)

Project volume: approx. EUR 245 million (44.6% financed by the BMW)

Timeline: 2021-2024 (followed by the establishment of the existing association “*Catena-X Automotive Network e.V.*” in 2021)

Goal: establishment of uniform standards for data and information flows along the entire automotive value chain; development of “SME-ready” data solutions

Description:

The flagship project Catena-X aimed to implement a **cooperative data ecosystem** operating along the automotive value chain, with the objective to enable manufacturers, suppliers and recycling companies to fully harness the potential of data. While many companies already stored and analysed their data, collaboration is challenging, which hinders the creation of seamless data chains (BMW, 2024^[78]).

By establishing a uniform data standard, project partners expect to improve performance in quality management and logistics processes, transparency regarding CO2 reductions and progress in product development. The **development of “SME ready” solutions** aims to integrate SMEs into the network by offering them low-cost and easily accessible solutions.

The developed solutions fall under various use cases such as Traceability, Sustainability and Digital Twins, all of which incorporate elements relevant to SMEs. For example, Catena-X has developed end-to-end traceability solutions that can be used through Excel uploads via standardised interfaces, enabling seamless integration with open-source, manufacturer-specific traceability systems (Catena-X Automotive Network, 2023^[79]).

The results of Catena-X and other projects under *Gaia-X for future mobility* will be gathered and made accessible through **Transfer-X**, a platform designed to establish a transformation hub for SME participation in the digital economy (budget: EUR 8 million, 2022-2025). This publicly accessible platform will offer the outcomes of the KoPa35c initiative available as target group-specific, standardised self-learning modules.

Manufacturing-X

While Catena-X (2021-2024) focused on the automotive industry, building on its results, the projects of the Manufacturing-X initiative (from 2023) (see Box 3.7) aim to create a cross-industry, open data ecosystem for the manufacturing sector, including both data on product and production. Manufacturing-X is a joint initiative by businesses, policy makers and academia, and in close collaboration with European and international stakeholders – with global collaboration institutionalised in the International Manufacturing-X Council.¹⁰ The BMW supports the Manufacturing-X initiative in Germany with an accompanying funding programme of around EUR 150 million, thereby, assisting cross-industry, pre-commercial collaborative projects led by an industry partner.

Box 3.7. Manufacturing-X (MX) (all relevant manufacturing sectors)

Budget: EUR 150 million (2024-2026 for consortia/subprojects)

Operated by: Federal Ministry for Economic Affairs and Energy (BMWE)

Timeline: 2024-2026

Goal: Support the creation of industrial data ecosystems channelled through consortia (R&D support)

Rationale: Industry 4.0 requires a common, open and trustworthy data ecosystem, in which all participants in the value chain can share their product and production data securely and interoperable. So far, there are few standardised data interfaces, each use case is unique.

Role of SMEs: SMEs are the primary users of developed applications. While project consortia are led by major industry companies, SMEs are present in the various consortia. Besides the technical implementation of the cross-industry data ecosystem, a main goal of Manufacturing-X is the transfer of the results through SME participation and development of “plug-and-play” solutions that are easily accessible to SMEs. A funding allocation of EUR 4 million is earmarked, starting in 2024, for establishing structures to transfer the results of R&D projects. Additionally, all sector-specific R&D projects include a transfer component.

Sector-specific projects (selection):

Factory-X: (Flagship-project with EUR 70 million of budget allocation with focus on **machinery sector**): Under the leadership of Siemens and SAP, 47 partners collaborate to develop a data ecosystem for factory equipment suppliers and operators on the basis of Catena-X results and concepts of *Platform Industrie 4.0*. The project focus on aspects such as data consistency across manufacturers, carbon footprint and energy management, digital “as-a-service” business models, and traceability of materials.

Robot-X: Robot-X aims to lower barriers for SMEs to entry into robotic systems and automation lines via the use of model-based systems engineering and AI.

Semiconductor-X: This collaboration between industry leaders and research partners develops digital twins for the semiconductor sector based on Catena-X and Gaia-X architectures. The digital twins model critical supply and value chain segments, while AI-based analysis intends to help companies master industry specific challenges (such as high throughput times, varying process yields and high product variance).

Transfer and cross-sectional projects:

DAVID: DAVID is a cross-sector project to ensure interoperability based on Asset of Administration Shells. Among other goals, the project is developing an SME “adapter” to make the data space accessible to SMEs.

Decide 4ECO: Decide 4Eco aims to create a digital tool that supports sustainability-focused decision-making across the entire product lifecycle and value chain in the manufacturing sector. Among other, the project develops interfaces, including a standardised Digital Product Passport.

ScaleMX:

This project aims to consolidate the strategy for transferring Manufacturing-X solutions, with a budget allocation of EUR 4 million. The goal is to facilitate the widespread implementation of these solutions across the industry by building the network’s capacity to transfer them.

Source: (BMWE, 2024^[80])

Beyond the flagship initiative Manufacturing-X, which targets various sectors including automotive, machinery and semiconductor, different modules of the 2020 economic stimulus package (KoPa 35c) have supported SMEs in the automotive sector. These include the above-mentioned module a2 to support the digitalisation of vehicle manufacturers and the supplier industry as well as the module b targeting medium-sized companies in the automotive sector. With over EUR 200 million (until Q1 of 2024), module b has supported the development of R&D projects for new vehicle and system technologies. The projects involve technologies for automated driving, innovative driveline concepts towards decarbonisation and system technologies, with a special focus on the promotion of SMEs. Finally, module c of the KoPa 35c establishes regional transformation networks (2021-2025) targeting the transformation of the automotive sector (see State policy programmes offer targeted support for manufacturing SME transformation).

Further SME-targeted R&D support programmes

The Federal Ministry of Research, Technology and Space (BMFTR)'s initiative **"SME-innovative"** (**"KMU-innovativ"**) supports cutting-edge research of SMEs in 11 areas of technological innovation.¹¹ This long-standing initiative was launched in 2007 and has since then supported more than 2700 individual and collaborative projects, involving around 4 379 SMEs. A main objective of this programme is the simplified access of funding for cutting-edge research for SMEs. This accessibility of the offer is facilitated through a dedicated advisory telephone service, a timely decision on the approval of funding within 2-3 month¹² as well as the application of particularly simple rules for proving the required equity capital for SMEs¹³ (BMFTR, 2023^[81]). Selected supporting guidelines for promotion of projects within the different areas of technological innovation such as *"SME-innovative: Future of Value Creation"* (2023-2024) (Box 3.8) place a strong emphasis on manufacturing SMEs.

Box 3.8. "SME-innovative: Future of Value Creation" ("KMU-innovativ: Zukunft der Wertschöpfung") (since 2023)

Type of support: Grants for individual R&D projects led by a single SME or collaborative projects involving one or more SMEs, with or without the participation of research institutions¹⁴, with variable amount of funding and two application windows per year.

Development of the programme: The guideline "Zukunft der Wertschöpfung" under "SME-innovative" evolved from its predecessor, the guideline on "Production research", to address the more wholistic nature of SME needs in response to industrial trends. For instance, the ongoing servicification of the manufacturing sector made it logical to consolidate research on production and services under a single guideline.

Thematic areas (selection) and target: Thematic areas eligible for project funding are: Innovative products, machines and equipment for industrial production; new manufacturing technologies and process chains; digitalisation and visualisation of production systems; innovative business models; new forms of collaboration in value creation networks; and robotics integration across value chains.

Due to the thematic areas of the R&D projects, as well as the evolution of the guideline from its predecessor on production research, so far, the majority of participating SMEs are from the machinery sector (58%) and other manufacturing industries (21%).

Current project example: "Humans and modular painting with robots (MemoLaRo)"

The MemoLaRo research project aims to develop a future-oriented painting workstation that significantly improves working conditions for employees in the painting process. The project focuses on creating assistive painting robots that use sensor systems and automatically generated painting programmes to paint components. The project runs over a period of three years and involves

collaboration between two SMEs and one research institution. By the end, it will produce a modern workstation with better ergonomics, reduced health risks, and the potential for widespread use in industries where small production batches are still painted manually.

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Source: (BMFTR, 2024^[82])

SMEs from all sectors, including the manufacturing sector, can also apply for R&D support under the R&D flagship programme the “Central Innovation Programme for SMEs (ZIM)”, managed by the Federal Ministry for Economic Affairs and Energy (BMWE) (see Box 3.9). In comparison to the initiative “SME-innovative”, which focuses on cutting-edge research in specified high-tech industries, the ZIM is a broadly applicable, technology- and sector-neutral funding programme, offering extensive support to a large number of SMEs. However, a recent evaluation of the *Central Innovation Programme for SMEs* (ZIM) showed that SMEs realising R&D projects often consider the above-described BMFTR-managed “SME Innovative” initiative as the main alternative to the ZIM¹⁵ (ZEW & Prognos AG, 2024^[83]). This reflects the comparable support services offered by both initiatives.

Box 3.9. Central Innovation Programme for SMEs (“Zentrales Innovationsprogramm Mittelstand (ZIM”))

Timeline: 2017-2024 (programme will be continued new upcoming guidelines in 2025)

Budget: EUR 694 million in 2023

Operated by: Federal Ministry for Economic Affairs and Energy (BMWE)

Type of support: Grants for individual or collaborative R&D projects (25-60% funding quota, max. EUR 550 000), all sectors

Target: Companies with less than 500 employees (max. of EUR 50 million in annual revenues); from January 2018 to July 2023 around 18 000 projects were supported.

Evaluation: The 2024 evaluation of the programme showcased its positive role in facilitating technology transfer, especially for SMEs with initially low levels of R&D intensity. The leverage effect on R&D spending is estimated at 1.9, meaning that for every euro of funding received, companies contribute an additional 90 cents towards research and development.

SME success story (machinery sector):

Through e-commerce, goods like textiles are often shipped in prefabricated standard boxes, which require filling of cavity by additional packaging materials, leading to additional paper and plastic waste. The medium-sized company *Hugo Beck Maschinenbau GmbH&Co.K* (110 employees), specialising in packaging machines and automated solutions, aimed to tackle this challenge. With the technical support by the *Central Innovation Programme for SMEs*, the company developed a variable and automatable packaging solution to save material, weight and transport space. The solution was successfully introduced into the market (BMWE, 2024^[84]).

Source: (BMWE, 2024^[84])

Business Development Services available to manufacturing SMEs

Further **SME-targeted support open to all sectors** is available through national programmes, which are not directly linked to sectoral initiatives. This includes the initiative “Funding of business consultancies for SMEs” (*Förderung von Unternehmensberatungen für KMU*) (see Box 3.10). To help SMEs navigate the opportunities and challenges of digitalisation, the BMWE launched the “Mittelstand-Digital”-initiative in 2015. This initiative established nationwide Mittelstand-Digital Innovation Hubs, serving as regional contact points where SMEs can access expert knowledge, technology demonstrations, networking opportunities, and training. Selected hubs specialise and share expertise in areas highly relevant for manufacturing SMEs adaption to megatrends. For instance, the “Klima.Neutral.Digital” Hub training climate coaches to develop climate neutrality roadmaps within SMEs, in particular specialising on digitally-supported optimisation of production process in the manufacturing industry (BMWE, 2024^[85]).

Box 3.10. Funding for external business consultancies for SMEs

Operated by: Federal Ministry for Economic Affairs and Energy (BMWE)

Type of support: Grant

Target: SMEs across all sectors (not specifically targeted towards manufacturing SMEs)

Budget: EUR 25-30 million per year (2023-2026), funding of up to 80% of costs, max. EUR 2800

Main objective and description:

The programme supports SMEs and freelancers seeking external consultancy. This funding covers advice on all aspects of business management, including economic, financial, personnel, and organisational matters (investment planning, optimisation of work processes, sustainability and environmental protection etc.).

Source: (BMWE, 2024^[86])

State policy programmes offer targeted support for manufacturing SME transformation

Germany's federal system divides power between the national government and the 16 federal states, which can lead to variations in the regulation and support of manufacturing SMEs across states. Regions with strong economic specialisations in manufacturing, particularly in the automotive industry – such as the Federal States of Baden-Württemberg and Bavaria – showcase robust and targeted state-level programmes to support SME transformation in manufacturing. In these two federal states, the automotive industry is particularly important, with a combined total of over 400 000 employees directly working in the automotive sector in the states (bayern-innovativ, n.d.^[87]).

These programmes not only complement national policy programmes, but they primarily serve as an initial point of contact for SMEs to access different kind of business support services (EU, national, and state level). As showcased by the two flagship programmes *Transformationswissen BW* and *Transformationslotse Bayern* (see Box 3.11), these policy programmes fulfil particularly important functions of:

- **Disseminating knowledge** (publications, workshops, seminars) targeted to a heterogeneous SME audience,
- Offering **training opportunities** to SMEs across varying levels of preparedness towards megatrends; this includes technical advice or business development services, or networking opportunities,
- Providing support to **navigate and identify suitable funding opportunities**,
- Offering a range of **networking opportunities**, by connecting SMEs with regional partners and networks (such as regional transformations networks, and thematic transformation hubs).

As supplement to the measures of the economic stimulus package (KoPa 35c) (see Targeted investment subsidies and R&D activities (digitalisation/ low-carbon transition/ resilience), the **Automotive Industry Fund** (“Zukunftsfonds Automobilindustrie”) provides support for strengthening the automotive industry at the regional level, through the establishment of regional transformations networks, and thematic transformation hubs. Those networks explicitly aim to promote and transfer knowledge to SMEs in automotive and component supplier industries. **25 currently active regional transformation networks** (funding volume of around EUR 161 million from BMWE) – implemented by project partners who feed in their expertise – focus on networking and exchange of experience between regional stakeholders and

automotive and component supplier industries and develop a regional transformation strategy. The regional transformation networks work together with **10 currently active thematic transformation hubs** (funding volume of around EUR 60 million). These are led by state agencies, or research institutions and specialise in specific issues such as electric mobility, battery hydrogen or digital infrastructure and software, thereby, aiming to improve knowledge transfer and raise awareness of resource efficiency and sustainable production in value chains. The hubs primarily serve as nation-wide point of contact between R&D stakeholders and companies, in particular SMEs.

Box 3.11. State policy programmes to support SMEs in the manufacturing sector

Transformationswissen BW (State of Baden- Württemberg)

The programme Transformationswissen BW (Transformation Knowledge BW) aims to support SMEs in the state of Baden- Württemberg in navigating ongoing transformations by offering an easily accessible and neutral point of contact. It emerged from the political dialogue format Strategiedialog Baden-Württemberg. The programme targets SMEs in the automotive industry including suppliers and SMEs in services (such as maintenance and repair) with the goal to collect and consolidate existing support services and making them widely accessible for SMEs. The state pilot centre, managed by the State agency e-mobil BW, offers concrete support to SMEs which is accessible through their online platform. The support is designed in collaboration with regional partners, existing networks, organisations and political stakeholders. Further, Transformationswissen BW and e-mobil BW support the 6 regional transformation networks active in the state of Baden-Württemberg.

More concretely, Transformationswissen BW supports SMEs with services which include external consulting, training, events relevant to the target group, or thematically relevant studies and informational materials. Concrete support activities include:

- **Database with over 400 publications**, including major publications and shorter documents of the format “Knowledge Compact” (Wissen Kompakt) to make technical knowledge in various areas of transformation (e.g., battery technologies, hydrogen powered fuel cells, semiconductors) accessible to a wide audience including SMEs;
- Database with over 300 training offers, gathering training offers including (online) seminars, advances study programmes from partners on regional and national level;
- Continuously updated event calendar, including SME-targeted workshops to support SME in product design and innovation, knowledge events (e.g., on latest developments and innovations in the field of battery technology and electric drivetrains), networking events – organised by e-mobil BW or partners.
- **Overview of current funding and advisory information**, targeted to SMEs and displayed in a database for companies to obtain an overview of various funding programmes.

One successful support instrument that received strong SME demand was the **consulting voucher “transformation automotive industry”** (Beratungsgutschein). Targeted specifically at medium-sized suppliers in the automotive industry (up to 250 employees), this voucher provided easy access to strategic consulting around the transformation of the automotive industry. The voucher covered financial support of up to 80% (and max. EUR 10 000 per voucher, max. 3 vouchers) to receive external advice (in strategy, diversification, business model development, data analytics etc.) by one of the consultants listed on *Transformationswissen BW*’s website. Overall, the programme, running from 2020 to 2024, received 800 applications from around 500 SMEs, with half of the applications received from the manufacturing sector and the other half from services (automotive trade and maintenance) (e-mobil BW, n.d.^[88]).

Success factors

Key success factors of Transformationswissen BW include **effective outreach and communication** with a diverse group of SMEs, followed by a **tailored needs assessment** conducted collaboratively with each company through a dedicated one-hour online call. Additionally, the programme offers a wide range of **support instruments tailored to different needs**, alongside access to experts in various fields, backed by a comprehensive **support network of thematic clusters and hubs**.

Transformationslotse Bayern (State of Bavaria)

Description, development of the programme and objectives

The programme *Transformationslotse Bayern* (Transformation Guide Bavaria) is a SME targeted programme and single point of contact to support SMEs in Bavaria in their process of transformation. The programme, managed by the State agency *Bayern Innovativ* (also one of the key implementing partners of the project *transform.by* to create 4 regional transformation networks) received its mandate from the Bavarian Ministry of Economic Affairs in 2020. Initially, the focus was on the Bavarian automotive industry, but since 2022 the support to advance SME transformation efforts was broadened to other sectors.

Concrete support instruments include:

- **Initial point of contact and needs analysis** through online call (around 1h) and self-assessment, and follow-up calls (over one thousand calls including over 70 physical visits of SMEs)
- The subprogramme called **“Funding guide”** (*Förderlotse*) helps SMEs with advanced project ideas navigate the funding landscape and identify and access suitable funding and advice,
- Organisation of events, event calendar and **weekly lecture series** along three core areas technology, markets, and cross-industry opportunities.

Success factors

Recognising the challenges SMEs face in choosing the right support, *Bayern Innovative* experts provide **targeted advice across sectors**. This helps SMEs navigate **transformation paths**, such as shifting from parts production to components manufacturing or from combustion engines to micromobility. The support responds a wide range of needs including idea generation, funding guidance, networking, and patenting assistance. Furthermore, many manufacturing SMEs, producing components for automotive or machinery sectors, often defy strict sector classification. Successful transformation relies on leveraging their **expertise to enter new markets**. Thus, one example of important support in this area is weekly lectures, such as the introduction to medical technology markets, a growing and highly regulated sector that offers potential opportunities, particularly for SME suppliers in the automotive industry. These lectures showcase market opportunities and help navigate regulations to facilitate market entry. As with the Transformationswissen BW programme, a key success factor is the **strong connection to a support network with dedicated expertise**. In this case, the ability to link SMEs with one of the 17 clusters established through the **Cluster Initiative Bavaria** (“Cluster-Offensive Bayern”, supported by Bavarian Ministry of Economic Affairs, Regional Development and Energy) plays a crucial role. These include clusters coordinated by *Bayern Innovativ*, such as Automotive, Medical Technology, Mechatronics and Automation, and New Materials.

Table 3.2. Summary of analysed policies in Germany

Investment Plan Name	Specific Initiative (if applicable)	Managing Entity	Scope of Implementation	Policy Instrument	Target Group	Budget	Addressed Megatrend
Forward-looking investments by vehicle manufacturers and their suppliers (economic stimulus package “KoPa 35c”) (2021) (EUR 2 billion)	Investment programme for modernising production (2021-2023)	BMWE	National	Investment Grants	Automotive SMEs	EUR 213 million	Digital, Low-carbon transition, Value Chains
-"	Module a2: Digitalisation of Vehicle Manufacturers	BMWE	National	R&D funding	Automotive value chain	EUR 362 million	Digital, Low-carbon transition, Value Chains
-"	Catena-X project (2021-2024) (part of module a2: “Digitalisation of Vehicle Manufacturers and the Supplier Industry”)	BMWE	National	R&D funding	Automotive value chain	Around EUR 110 million	Digital, (Low-carbon transition,) Value Chains
-"	Transfer-X project (2022-2025)	BMWE	National	Digital training platform	Automotive SMEs	8 million	Digital, (Low-carbon transition,) Value Chains
-"	Manufacturing-X (2024-2026)	BMWE	National	R&D funding and transfer	Manufacturing sector	EUR 150 million	Digital, Low-carbon transition, Value Chains
-"	New vehicle and system technologies	BMWE	National	R&D funding	Automotive value chain	EUR 764 million	Digital, Low-carbon transition, Value Chains
Automotive Industry Fund (“Zukunftsfonds Automobilindustrie”)	Transformation Networks and Thematic Transformation Hubs	BMWE	Regional/National	Networking, Exchange, Training	Automotive value chain	EUR 221 million (2022-2026)	Digital, Low-carbon transition, Value Chains
SME-innovative (“KMU-innovativ”) (2007-2024) (around EUR 2 billion of funding used since 2007)	SME-innovative: The future of value creation (selected example) (since 2023) („KMU-innovativ: Zukunft der Wertschöpfung“)	BMFTR BMBF	National	R&D funding	SMEs, especially in manufacturing and industry	n.a.	Digital, (Low-carbon transition, Value Chains)
Central innovation Programme for SMEs (2017-2024)		BMWEK	National	R&D funding	SMEs	EUR 694 710 million (in 2023)	Digital, Low-carbon transition, Value Chains
Funding for external business consultancies for SMEs (2023-2026)		BMWEK	National	Grants for external consulting (BDS)	SMEs	EUR 25-30 million per year	Digital, Low-carbon transition, Value Chains

Federal programmes (selection)	Transformations-wissen BW (since 2020)	e-mobil BW (state agency Baden-Württemberg)	Federal/regional	Guidance, Training, Exchange, Networking	Automotive SMEs	n.a.	Digital, Low-carbon transition, Value Chains
..	Transformationslotse Bayern (since 2020)	Bayern-innovativ (state agency Bayern)	Federal/regional	Guidance, Training, Exchange, Networking	Manufacturing SMEs	n.a.	Digital, Low-carbon transition, Value Chains

Note: This table provides an example of the policies researched by the OECD for this project and does not offer a comprehensive overview of the country's policies in the manufacturing sector.

Source: OECD analysis based on desk research and stakeholder interview.

Conclusion

German government policy features a strong emphasis on SMEs in the manufacturing sector, through different programmes, including SME-targeted measures, that focus on R&D activities, business support services and knowledge transfer. The support is particularly concentrated in the key industry, the automotive sector, encompassing services for the variety of SMEs involved in the automotive value chain. Broader cross-sector SME-targeted R&D support programmes (ZIM) as well as more specialised R&D support initiatives for high-tech sectors ("SME-innovative") receive overall strong interest and uptake by manufacturing SMEs. Furthermore, flagship initiatives such as the Manufacturing-X project also involve R&D projects for different sectors including machinery and semiconductor industries with the goal to create collaborative data ecosystems for the manufacturing industry. However, the success of these policy measures hinges on successful transfer of knowledge and solutions to SMEs for which also major efforts are currently underway.

Major policy initiatives in Europe and Germany (such as in the area of electric mobility and semiconductors) have set the direction for the German industry and have benefitted manufacturing SMEs in their adaption to ongoing megatrends. At the same time, policy changes, such as the sudden halt of environmental bonus for EVs, have also created uncertainty in the markets and for SMEs in the value chain. Furthermore, SMEs reliant on the traditional car industry, such as internal combustion engine component manufacturers, and those unwilling or unable to shift production methods or product lines, face mounting challenges in adapting to the changing market landscape. In this context, institutional support through SME-targeted programmes from regional partners, including state agencies, plays a crucial role in facilitating adaptation among a diverse group of SMEs. These agencies provide manufacturing SMEs with guidance and targeted assistance, while also supporting the implementation of major national government programmes, such as regional transformation networks, and thematic hubs.

Japan

Introduction

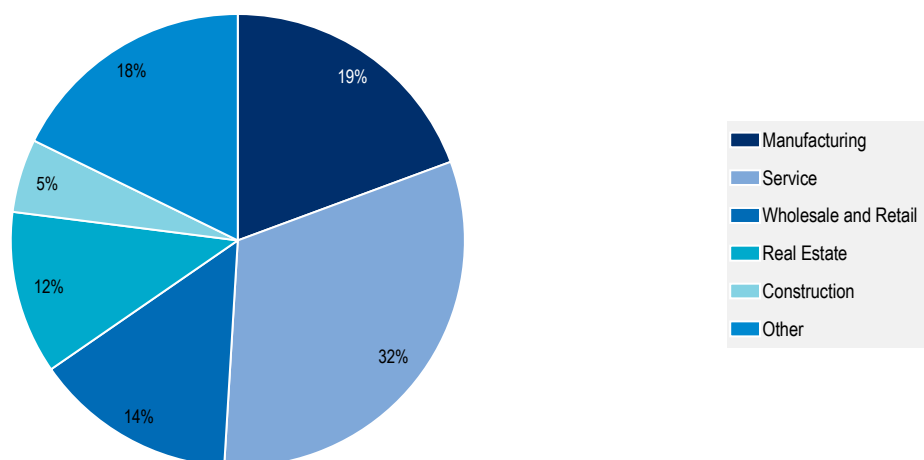
The manufacturing sector is a cornerstone of Japan's economy, contributing 19.4% to the country's GDP in 2022 (Figure 3.8) and employing 15.5% of the workforce in 2023¹⁶ (Figure 3.9). Furthermore, labour productivity in manufacturing was 24.7%¹⁷ higher than the average across all sectors in 2022 (METI, 2024^[89]). Over 2012-22, productivity per capita in the manufacturing sector grew by 8%¹⁸, against 4% growth across all sectors, highlighting its importance as an engine of Japan's economic growth.

Japan is a world leader in the use of robots and AI, driven by a significant labour shortage due to its aging population. As illustrated in Figure 3.10, over 2007-2022 the share of employees aged 15 to 34 decreased by close to 5 percentage points, standing at 24.4% in 2022. This push for innovation has accelerated the spread of autonomous vehicles and strengthened semiconductor manufacturing capabilities, both critical for advancing AI technologies.

Japan faces energy challenges due to its reliance on imported fossil fuels. To break away from excessive dependence on fossil fuels and achieve a supply-demand structure that can withstand an energy crisis, it needs to secure "3E" energy goals (energy security, economic efficiency, and environment). To address this, Japan is making efforts to rapidly transition towards renewable energy and nuclear power, aiming to increase their share from 27% in 2022 to 56-60% by 2030. Additionally, energy conservation efforts aim to maintain 2030 energy consumption at 2019 levels (METI, 2021^[90]).

Figure 3.8. Manufacturing sector's contribution to total value added in Japan in 2022

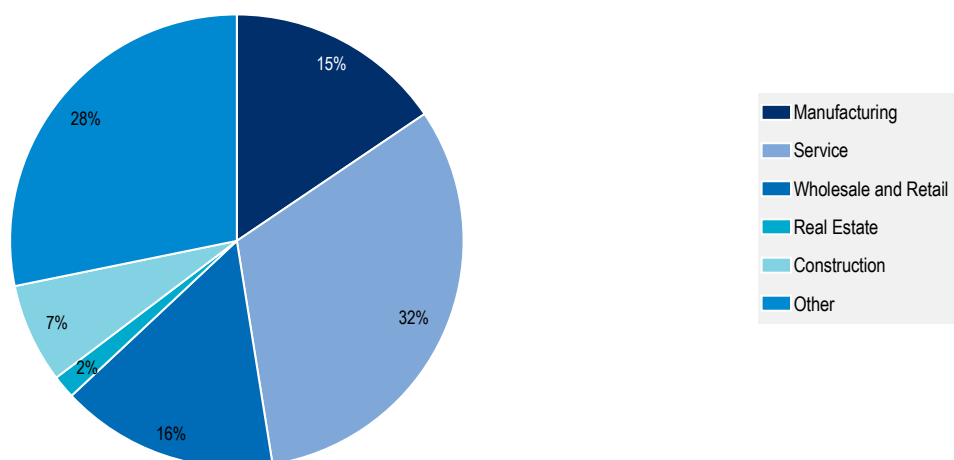
As a share of total gross value added generated in Japan in 2022



Source: (METI, 2024^[89])

Figure 3.9. Manufacturing sector's contribution to total employment in Japan in 2022

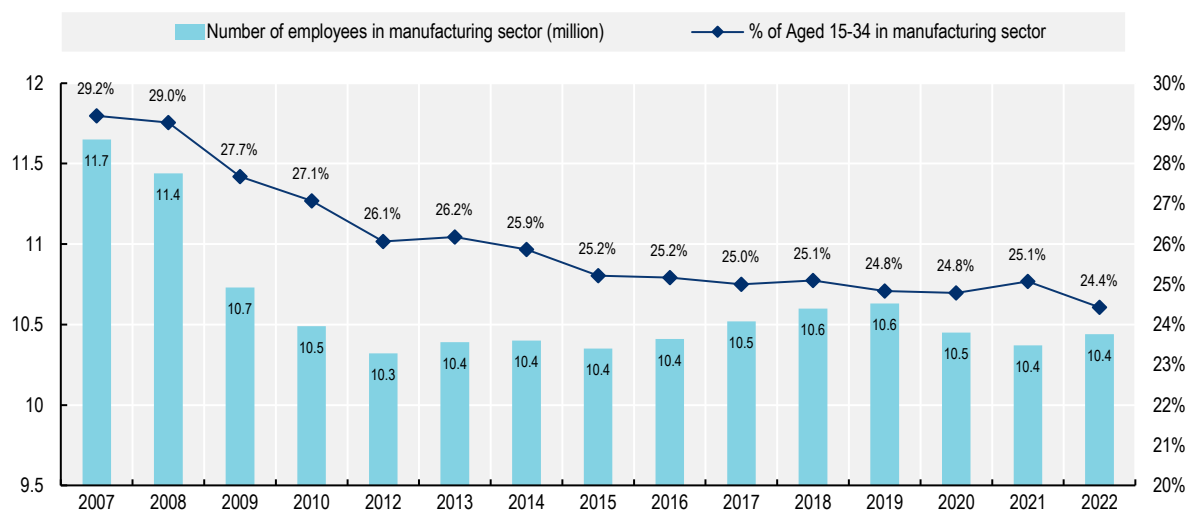
As a share of total number of employees in Japan in 2022



Source: (MIC, 2022^[91])

Figure 3.10. Number of employees and share of young employees in manufacturing sector in Japan

As total number of employees in manufacturing sector and the share of employees aged 15-34 years in the sector in Japan



Note: The data in 2011 was not reported because of the 2011 off the Pacific coast of Tohoku Earthquake

Source: (MIC, 2022^[91])

Manufacturing SME readiness

Overview

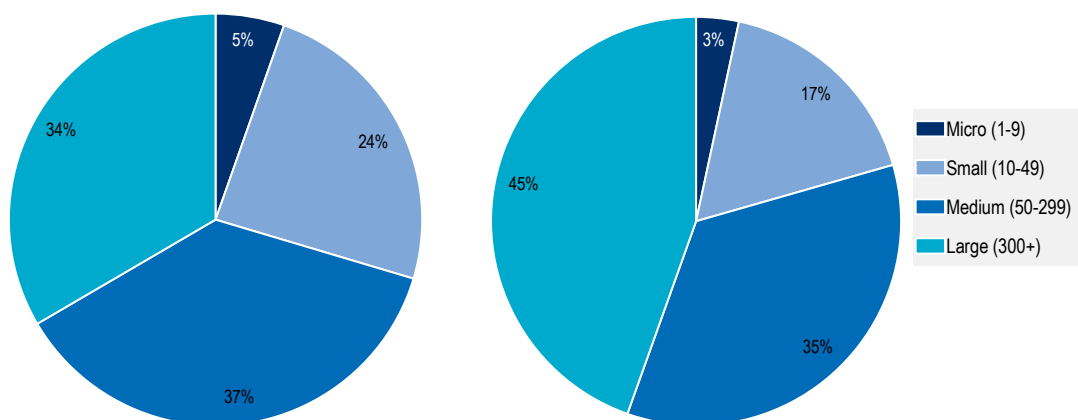
The manufacturing sector in Japan, including the automotive, semiconductor and machinery industries, is being reshaped by the combined effects of the transition towards lower-emission production, the adoption of digital technologies and evolving geopolitical developments.

The manufacturing sector is a significant source of greenhouse gas (GHG) emissions and, therefore, plays a crucial role in efforts to reduce these emissions. According to National Institute for Environmental Studies (NIES, 2021^[92]), the manufacturing sector is responsible for 23.3 %¹⁹ of total CO₂ emissions in Japan in 2021. The machinery category, which includes automotive and semiconductor industries, accounts for 0.8% of total emissions²⁰. As for SMEs in this sector, they have significant impact as SMEs account for 66% of employees and 55% of value-added (Figure 3.11). Moreover, as labour shortages intensify in Japan, with only 76.3%²¹ of job positions filled, the demand for digitalisation, including autonomous vehicles, AI chips, and smart factories continues to grow. Additionally, geopolitical tensions are reshaping supply chains and prompting Japan to enhance its capacity to produce essential goods and limit the export of semiconductors and machines.

Figure 3.11. SME's share of gross value-added number of employees in manufacturing sector in Japan in 2021

Panel A. Share of employees by business size

Panel B. Share of value-added by business size



Source: (METI, 2021^[93])

Low-carbon transformation

The transition towards lower-emission and more resource-efficient production is essential for Japanese SMEs, especially as the government targets carbon neutrality by 2050. The GX promotion Strategy (Cabinet Secretariat, METI, Cabinet Office, etc., 2023^[94]) highlights the importance of SMEs especially in the automotive sector, where SMEs form a significant part of the supplier base ²². However, SMEs often face challenges in adapting to these developments due to limited resources and expertise. According to Forbes Japan, only 20% of SMEs have successfully implemented GX initiatives. In a recent survey, 28.9%

of companies that recognised the need for GX but have not yet taken action cited the lack of skilled personnel as the main reason for inaction (Forbes Japan, 2023^[95]).

Digital transformation and labour shortage

Japanese SMEs are experiencing critical labour shortages, primarily driven by an aging workforce. The demographic shift is making it increasingly difficult to attract younger workers while raising the risk that valuable tacit knowledge and technical expertise will be lost as experienced employees retire. An ageing workforce can also create additional challenges for productivity, including difficulties in adapting to new technologies and evolving work processes. In many SMEs, insufficient succession planning and limited leadership renewal further exacerbate risks to business continuity and can reduce the attractiveness of these firms to younger generations. While many SMEs have sought to address labour shortages and productivity pressures through digitalisation, their efforts often remain focused on external recruitment rather than on internal strategies to improve employee satisfaction, retention, and work environment quality (JILPT, 2020^[96]).

Additional drivers of increasing labour shortages include declining birth rates, and increased competition from large corporations, which often provide more competitive salaries and benefits (SMEA, 2024^[97]). This puts SMEs at a disadvantage when it comes to attracting and retaining skilled workers. In response, the government has introduced various measures, such as promoting a work environment that encourages greater participation from women, elderly workers, and foreign nationals.

Many SMEs continue to struggle with their digital transformation, which has been identified as a key issue to attract and retain talent. The government's Action Plan for Realising Work Style (Council for the Realization of Work Style Reform, 2017^[98]) emphasises the need for SMEs to adapt to new work styles and technologies, such as teleworking and leveraging data, to attract younger generations and to improve labour efficiency. There are some cases of SMEs who are successful in dealing with digital transformation as illustrated in Box 3.12. Nevertheless, many SMEs struggle with the digital infrastructure and managerial expertise required to implement such reforms effectively. The data provided by the MIC in 2021 showed that only around 30% of SMEs had adopted remote work practices, citing concerns over cybersecurity, operational efficiency, and employee monitoring (MIC, 2021^[99]).

Box 3.12. The electric manufacturing company in Niigata prefecture, Japan

In Niigata Prefecture, Japan, a metal processing company successfully undertook a digital transformation project for its production processes. Many of the company's veteran employees, aged 60 and older, play key roles, as there is no mandatory retirement age. These skilled workers are integral to producing a wide variety of products in small quantities, but the company faced challenges with meeting deadlines and managing production.

The initial implementation of a packaged system failed due to its complexity for older employees. In response, the company introduced a new production management system incorporating AI voice recognition technology. By customising the system based on feedback from the shop floor, the company improved progress tracking and operational efficiency. Leveraging data also enhanced productivity, enabled better client negotiations on pricing, and reduced overtime, which boosted value-added per minute. Employees have gained a deeper understanding of digital technologies, and the company continues to drive management improvements through data utilisation.

Source: (JFC, 2022^[100])

SME resilience amidst economic shocks and supply chain disruptions

Japanese SMEs are particularly vulnerable to economic shocks and supply chain disruptions, as illustrated by the impact of the COVID-19 pandemic and the subsequent global supply chain crisis. According to the Small and Medium Enterprises Agency of Japan (SMEA), many SMEs operate with limited financial reserves and heavily rely on specific suppliers, making them susceptible to sudden interruptions in the flow of goods and raw materials. The impact of these disruptions is magnified by the fact that SMEs often lack the financial flexibility and negotiation power of larger corporations, leaving them unable to secure alternative suppliers in times of crisis (SMEA, 2024^[97]). In response to these vulnerabilities, the Japanese government has introduced a series of measures aimed at strengthening the resilience of SMEs. The subsidy programme for business restructuring and diversification (METI, 2024^[101]) was established to support SMEs in diversifying their supply chains.

The pandemic also highlighted the importance of digitalisation in maintaining supply chain continuity. The Ministry of Economy, Trade, and Industry of Japan (METI) survey from 2021 showed that SMEs with more advanced digital infrastructure were better able to navigate disruptions by leveraging data for real-time inventory management and alternative sourcing (METI, 2021^[102])²³.

Government policy (automotive, machinery and electronics)

Overview: Society 5.0 and SIP program

Society 5.0 is Japan's vision for a "super-smart society", integrating advanced technologies such as AI, IoT, robotics, and big data into all aspects of life to address societal challenges like an aging population, environmental sustainability, and economic stagnation. It aims to create a human-centered society where digital transformation improves quality of life and drives innovation across sectors, from healthcare to mobility (Cabinet Office of Japanese government, 2015^[103]). Complementing this, the Cross-ministerial Strategic Innovation Promotion Programme (SIP) is a Japanese government initiative designed to advance science and technology research to solve critical national issues. SIP focuses on fostering innovation in areas like energy, infrastructure, disaster management, and health, with a goal to enhance Japan's global competitiveness and address domestic challenges in line with the Society 5.0 vision (Box 3.13).

In addition to this, METI published the 2024 white paper on manufacturing which discusses smart manufacturing practices and presents some initiatives to support its expansion. In light of recent survey results, highlighting challenges in promoting digitalisation within the manufacturing sector, especially to enhance employee awareness and digital skills. METI is developing guidelines to enhance support for digital transformation (DX) investment and implementation in the manufacturing sector. These guidelines focus on helping manufacturers address management challenges and promoting understanding of the methods and processes necessary for optimisation and successful implementation of smart manufacturing initiatives. The framework covers factors like external and internal influences, transformation challenges, standardisation, project design, and examples of successful smart manufacturing initiatives (METI, 2024^[89]).

Japan is harnessing digital innovations to tackle environmental challenges and achieve carbon neutrality by 2050. Japan has reduced greenhouse gas emissions by 19.3% from 2013 to 2022 and aims to achieve carbon neutrality by 2050. To achieve this goal, the government launched a 10-year JPY 150 000 billion green transformation program, including a JPY 2 000 billion Green Innovation Fund²⁴ and the 2023 GX Promotion Act, which supports further technological advancements through bonds, carbon taxation, and a carbon trade market.

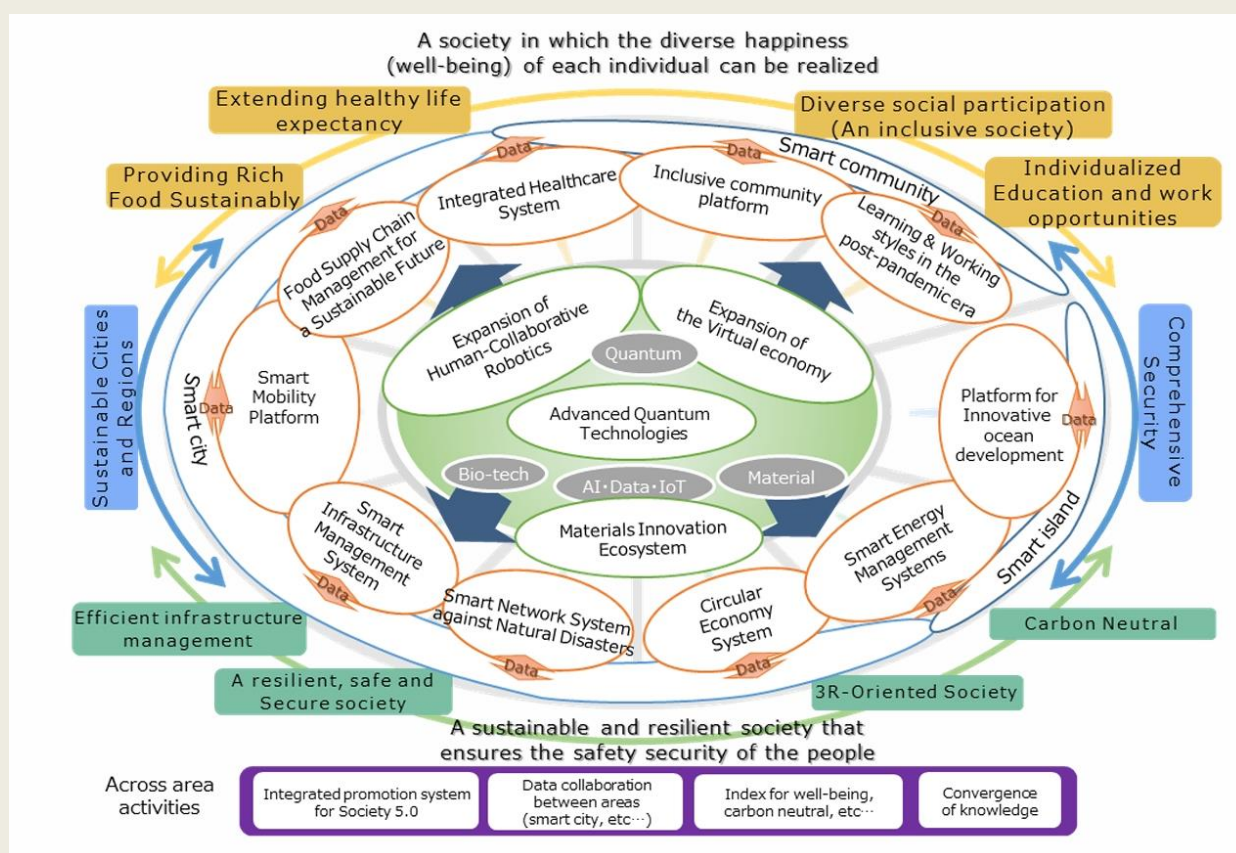
In parallel, Japan is addressing the semiconductor shortage and advancing digital technologies through METI's Semiconductor and Digital Strategy, which includes a JPY 1 067 billion Semiconductor Fund and initiatives to accelerate AI, autonomous vehicles, and supply chain digitalisation. Additionally, Japan's Economic Security Promotion Act, created in 2022, aims to mitigate geopolitical risks by securing critical products like semiconductors and robotics, supported by a 2 trillion JPY fund for economic security technology development. By fostering innovation and resilience in the manufacturing sector, these initiatives aim to ensure that companies can navigate both current and future challenges while contributing to Japan's overall economic stability.

Box 3.13. Strategic Innovation Promotion Program (SIP)

The cabinet office of Japan set up target areas where the development and diffusion of innovative technologies and reform of social systems are required beyond the boundaries of conventional industries and fields, in order to realise "Society 5.0" objectives.

Rather than working independently in each area, the programme will work toward the realisation of Society 5.0 through the development of an integrated promotion system, data collaboration among areas, the development of common indicators related to cross-cutting social issues such as well-being and carbon neutrality, and the use of comprehensive knowledge for the construction of social systems.

Figure 3.12. Target areas in the next SIP to realise "Society 5.0"



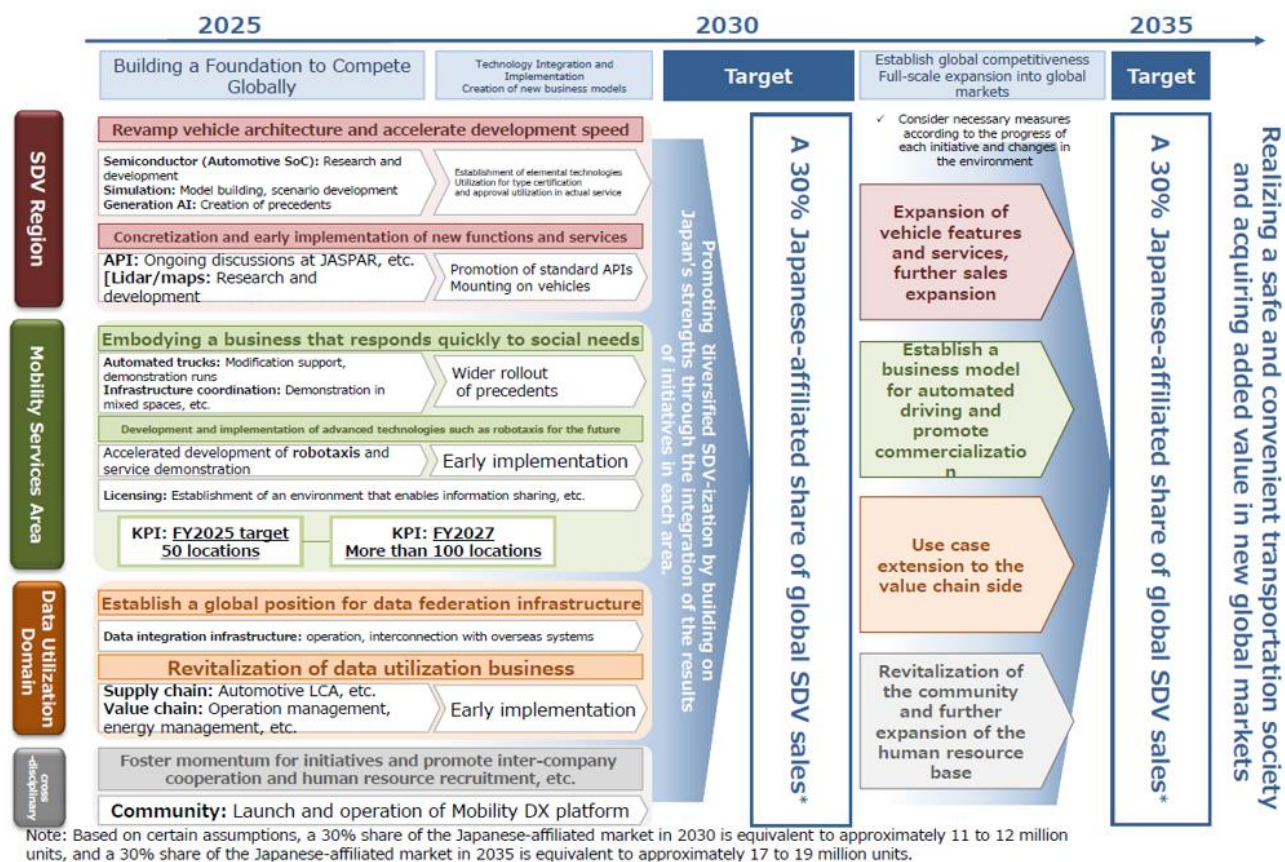
Sources: (The Cabinet Office of Japan, 2022^[104]) (Secretariat of Science, Technology and Innovation Policy, 2023^[105])

Mobility: Mobility Digital Transformation (DX) Strategy

Japan views software-defined vehicles (SDVs), mobility services, and data utilisation as key areas of global competition and recognises the need for stronger public-private collaboration. Accordingly, the Ministry of Economy, Trade and Industry (METI) and Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has launched the "Mobility DX Strategy," aiming to capture a 30% share of SDVs by 2030 and 2035 through the development of "multi forms of SDVs across various price and functionality ranges (Figure 3.13). This initiative includes efforts in areas such as API standardisation, semiconductors (SoC), simulation,

generative AI, LiDAR, high-precision 3D maps, and security. It also promotes projects like automated vehicle implementation and the Ouranos ecosystem²⁵ for secure data utilisation. Furthermore, the "Mobility DX Platform" aims to facilitate collaboration among industry, startups, and academia.

Figure 3.13. Roadmap on the Japanese Mobility DX Strategy



Source: (METI, 2024_[106])

Box 3.14. Digital Lifeline Development Plan

The Digital Lifeline Development Plan is a 10-year masterplan, involving significant investment from both the public and private sectors to create a digital infrastructure with standardised hardware, software, and regulations. This will speed up the social implementation of innovations such as CAV (Connected Autonomous Vehicles) and AI, contribute to address issues like labour shortages, and help create local living areas where the cyberspace and physical space are highly integrated.

Japan has launched four Early-harvest projects, developing UAS (Urban Aircraft System) corridors from 180km in 2024 to 50,000km in 2034, CAV corridors from 100km in 2024 to all major highways in 2034, implementing digital transformation of infrastructure management from two major cities in 2024 to 50 major cities in 2034 and Okunoto Digital Lifeline.

As for automotive sector, to address labour shortages and enable the free movement of people and goods according to demand, it is establishing "CAV corridors" to facilitate autonomous vehicles through hardware, software, and rules. These corridors support autonomous driving by providing vehicles with information on the surrounding environment detected by cameras, LiDAR, and other sensors. Additionally, they sometimes set priority lanes for autonomous vehicles; On the Shin Tomei Expressway, approximately 100 km between Suruga Bay Numazu SA and Hamamatsu SA, designated for the priority use of autonomous vehicles to facilitate the realisation of autonomous driving by fiscal year 2024. These corridors will ensure the safe and efficient operation of self-driving cars. In 2024, it plans to designate over 100 km of priority lanes for autonomous vehicles on sections of the Shin Tomei Expressway to enable the operation of autonomous trucks.

The policy is characterised by the vertical launch of the entire supply chain by identifying the elements necessary for automated services, investing in each of them, and developing new rules with the co-operation of the government and the private sector.

Figure 3.14. Digital Lifeline Related Financial Support Policy Overview in 2024



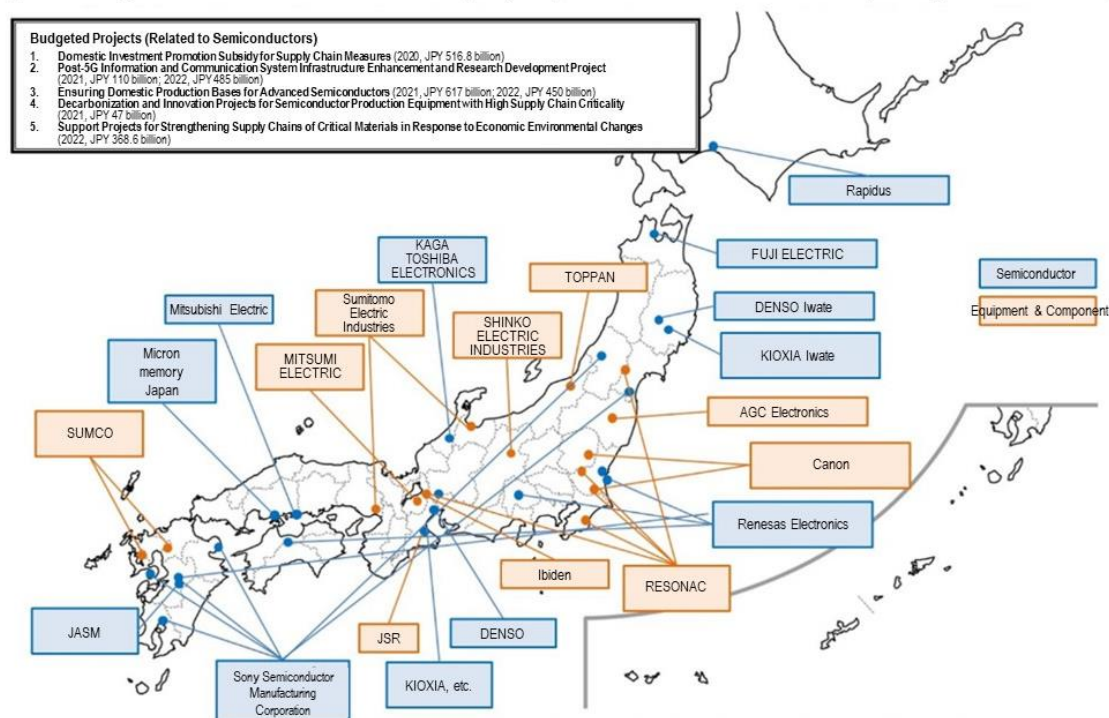
Source: (METI, 2023^[107])

Electronics (Semiconductor)

METI revised its Semiconductor and Digital Strategy in 2023, driven by urgent requirement to mitigate intensive shortage of semiconductors due to Covid-19 and rising demand for chips because of advancing digital technologies, such as AI and big data analysis. METI developed Specified Semiconductor Fund with JPY 1 699.2 billion. It also utilises the Green Innovation Fund, the Economic Security Fund, and tax credit based on production. METI has enhanced stable supply with existing technologies and invested in R&D of future technologies. As a result of strategic investments by the government and funds, large-scale semiconductor investment projects worth JPY several tens of billions each are starting to take shape across Japan (Figure 3.15).

Figure 3.15. Large-scale domestic investment projects in Japan related to semiconductors

Examples of large-scale domestic investment project (related to semiconductors) with government support



Source: (The GX Implementation Promotion Office of the Cabinet Secretariat, 2023^[108])

Machinery

Japanese policies on machinery are based on *The Initiatives for Ensuring the Stable Supply of Machine Tools and Industrial Robots*, established by METI to strengthen the resilience and competitiveness of the country's manufacturing base. The initiatives aim to ensure a stable domestic supply of critical manufacturing equipment while reducing vulnerabilities arising from disruptions in global supply chains. At the same time, they seek to support technological innovation and maintain Japan's competitive position in advanced manufacturing technologies.

A strong emphasis is placed on the role of SMEs and on fostering collaboration among firms, research institutions and other stakeholders to strengthen the domestic manufacturing ecosystem. The initiatives also incorporate measures to improve energy efficiency and support technological advances in machine

tools. For example, research has focused on the application of new structural materials, such as carbon fibre reinforced plastics (CFRP), to machine tools and on the development of advanced control methods to optimise their performance. These innovations are expected to reduce energy consumption through both lower power requirements and improved machining efficiency. The project targets total energy savings of 20%, comprising a 15% reduction in power consumption and a further 5% gain through enhanced machining efficiency (NEDO, 2015^[109]). In addition, METI supports the stable supply and technological upgrading of the machine tool and industrial robotics sectors through subsidy programmes aimed at strengthening production capabilities and fostering innovation among key industry players (see Table 3.3).

Table 3.3. Examples of major governmental financial support in Japan for the machinery sector

Financial support for specific companies	Major products
JPY 20 billion for Fanuc	CNC System
JPY 8 billion for Mitsubishi Electric *Including CNC system and PLC	Servo
JPY 3 billion for Yaskawa Electric	PLC
JPY 6 billion for Nidecdrive Drive Technology	Decelerator
JPY 3 billion for Harmonic Precision	Decelerator

Source: (METI, 2023^[110])

Policies for SMEs

SMEs can access a range of government support programmes, including the Business Restructuring Subsidy and the Manufacturing Subsidy, which help firms invest in innovation, productivity improvements and business transformation. Additionally, METI launched the Mikata Project to support SMEs in the automotive sector to transform their business model for CASE era, by providing training program, offering individual consultation, dispatching experts, and introducing subsidies (Box 3.15). Furthermore, major investments in semiconductor manufacturing are creating new business opportunities for domestic suppliers. For example, Japan Advanced Semiconductor Manufacturing (JASM), which has invested USD 8.6 billion in new chip production facilities, aims to source around 60% of its equipment and materials from Japanese companies, creating significant opportunities for local SMEs and manufacturers (JASM, n.d.^[111]).

Box 3.15. Mikata project

The Mikata project is designed to support SMEs in the automobile parts industry as they navigate the shift towards electrification and digitalisation. This initiative addresses the needs of SMEs, which are crucial suppliers in the automotive supply chain but may face challenges adapting to new technologies and market demands brought about by the electrification and digitalisation of automobile. “Mikata” means “view” and “ally” in Japanese, meaning this project provides a “view” for SMEs involved in the automotive industry to respond to CASE, and supports them as an “ally” of the company. The project includes:

- On-site training and seminars: Free seminars on the latest information on the automotive industry, such as carbon neutrality and EVs, as well as hands-on training (e.g., exhibition of electric vehicle parts, etc.).
- Individual consulting services: Experienced experts provide consultation on CASE-related issues and help companies sort out issues in accordance with their own circumstances.
- Dispatch of Experts free for five times: Technical issues and support for accompanying the company in its strategy formulation, technological development, and other specific issues. This project provides services with over 300 experts able to provide individualised consulting to each company, covering SMEs in all 47 prefectures.
- Capital Investment Subsidy

Source: (METI, 2024^[112])

Table 3.4. Summary of analysed policies in Japan

Investment Plan Name	Specific Initiative (if applicable)	Managing Entity	Scope of Implementation	Policy Instrument	Target Group	Budget	Addressed Megatrend
Green transformation (GX) promotion budget projects	Storage battery manufacturing supply chain	METI	National	Subsidy	Automotive sector	JPY 230 billion	Low-carbon transition, Value chains
-"	GX supply chain development	METI	National	Subsidy	Automotive sector, Manufacturing sector	JPY 421.2 billion	Low-carbon transition, Value chains
-"	Deep-tech startups in the GX field	METI, NEDO	National	Subsidy	SMEs in the GX fields	JPY 41 billion	Low-carbon transition
-"	Capital contribution to the decarbonization growth-oriented organization	METI, GX Acceleration Agency	National	Investment Grants	GX investors	JPY 120 billion	Low-carbon transition
Innovative storage battery development project for electric vehicles		METI, NEDO	National	Subsidy	Automotive sector	JPY 2.4 billion	Low-carbon transition
Promotion the installation of charging and refueling infrastructure for energy vehicles	Charging and hydrogen refueling infrastructure development project	METI	National	Subsidy	Automotive sector	JPY 10 billion	Low-carbon transition

Green innovation fund	Next-generation Storage Battery and Motor Development	METI, NEDO	National	Subsidy	Automotive sector	JPY 151 billion	Low-carbon transition
..	Development of in-vehicle computing and simulation technologies for energy efficiency in electric vehicles and others	METI, NEDO	National	Subsidy	Automotive sector	JPY 42 billion	Digital, Low-carbon transition
..	Development of an IoT sensing platform for next-generation digital infrastructure	METI, NEDO	National	Subsidy	Semiconductor sector	JPY 56.9 billion	Digital, Low-carbon transition, Value chains
Digital infrastructure development project for industrial DX	Uranus ecosystem	METI, IPA, NEDO	National	Subsidy	Manufacturing sector	JPY 2 billion	Digital
Support project for business transformation of automotive parts suppliers	Mikata Project	METI	National	Subsidy	SMEs in automotive sector	JPY 0.6 billion	Digital
R&D project for strengthening dynamic capabilities in the manufacturing industry	5G and other technologies	METI, NEDO	National	Subsidy	Manufacturing sector	JPY 0.6 billion	Digital
Demonstration and support project for CASE initiatives	Including autonomous driving and MaaS	METI	National	Outsourcing	Automotive sector	JPY 4.9 billion	Digital
Specified semiconductor fund		METI, NEDO	National	Subsidy, Interest subsidy	Semiconductor sector	JPY 1 699.2 billion	Digital
K program fund(Economic Security program)		METI, NEDO, JST	National	Subsidy	Semiconductor sector, Machinery sector	JPY 250 billion	Digital, Low-carbon transition, Economic security
Productivity revolution promotion project	Manufacturing subsidy for SMEs, IT implementation subsidy	SME Agency	National	Subsidy	SMEs	JPY 580 billion	Digital, Low-carbon transition
Business restructuring project for SMEs		SME Agency	National	Subsidy	SMEs	JPY 200 billion	Digital, Low-carbon transition

Note: This table provides an example of the policies researched by the OECD for this project and does not offer a comprehensive overview of the country's policies in the manufacturing sector.

Source: OECD analysis based on desk research

Conclusion

Japan has established clear strategic priorities for the automotive, semiconductor and machinery sectors, supported by substantial financial incentives. Across these strategies, digital transformation is promoted as a key enabler of both emissions-reduction objectives and supply chain resilience. Several initiatives specifically target SMEs, helping them adapt their business models, upgrade capabilities and seize new opportunities as digitalisation and sustainability transitions reshape industrial ecosystems.

At the same time, acute labour shortages, population ageing and the slow adoption of new work practices continue to constrain SMEs' ability to advance their digital and sustainability-related transformations. These challenges risk widening productivity and innovation gaps between SMEs and larger firms.

To address these challenges, Japan has adopted a comprehensive policy approach that combines regulatory measures, public investment and tax incentives. The automotive and semiconductor sectors have been a particular focus of support, reflecting their strategic importance for economic competitiveness, technological leadership and supply chain security. In the machinery sector, policy attention has increasingly focused on strengthening domestic production capabilities and reducing vulnerabilities associated with external dependencies and supply chain disruptions. More broadly, the government is seeking to support manufacturing SMEs in adapting to demographic pressures and structural economic change through digital transformation initiatives and targeted business support measures.

Japan's approach is underpinned by a long-standing tradition of public-private collaboration, with government, industry and other stakeholders working together to develop strategic priorities and investment plans. Recent policy initiatives appear to have strengthened private-sector investment momentum, reflecting growing business confidence in strategic sectors and the government's commitment to supporting industrial transformation (Cabinet Secretariat, METI, Cabinet Office, etc., 2023^[113])²⁶.

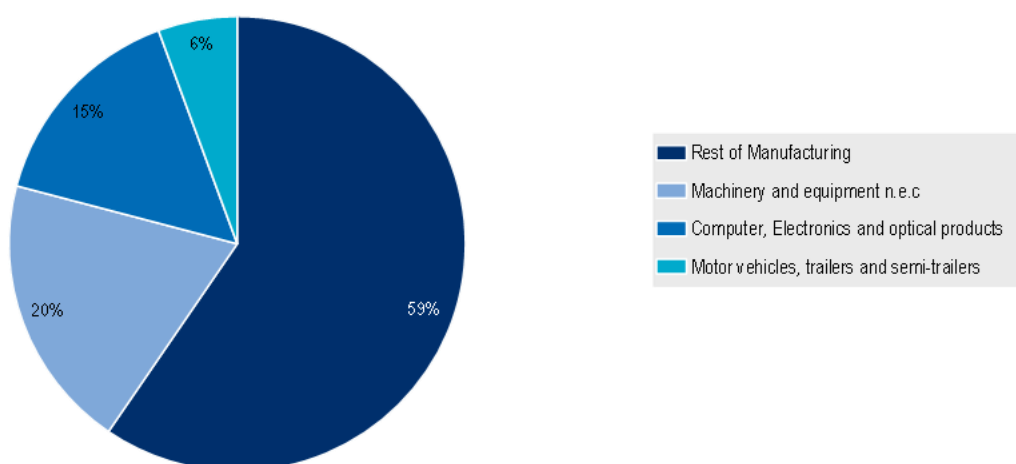
Korea

Introduction

Korea plays a leading role in the global manufacturing industry, contributing 28% of the world's manufacturing output. At the national level, SMEs account for 96.9% of all manufacturing firms, employ 67.0% of the workforce and generate 34.1% of the total value added in this sector (MSS, 2022^[114]). Given the sector's importance, the government has prioritised raising awareness among firms about ongoing megatrends that are expected to reshape the economic landscape. In response to these megatrends, it is essential to ensure sufficient levels of investment to secure the necessary human capital, advanced technology and modern equipment. This is particularly crucial for maintaining competitiveness in key subsectors such as machinery, automotive and electronics, where investments are pivotal. These three subsectors together account for 41% of the total manufacturing industry investment, illustrating their significance in Korea's economy, as shown in Figure 3.16.

Figure 3.16. R&D spending by subsector

As a percentage of total spending in R&D in the manufacturing sector in KRW



Source: (KOSIS, 2022^[115])

The transition towards lower-emission production poses significant challenges for Korea's economy. Korea had the lowest share of renewable energy in primary energy supply among OECD countries, at 1.44% in 2020, well below the OECD average of 7.89% (OECD, 2020^[116]). Given the prominence of energy-intensive industries such as steel, electronics and shipbuilding, reducing emissions while maintaining industrial competitiveness remains a key policy challenge.

Korea's active labour force peaked in 2019 (KOSIS, 2024^[117]) and has since experienced a steady decline. Therefore, productivity gains from Industry 4.0 technologies are essential to sustaining current levels of economic output. Additionally, many manufacturing SMEs are owned by an ageing generation nearing retirement, posing a further challenge for the future of the sector (see Box 28).

Strengthening supply chain resilience has become a key policy priority in Korea, reflecting the country's exposure to geopolitical tensions and global trade disruptions. With China and the United States accounting for 25.0% and 21.9% of goods exports respectively (Korean Customs Service, 2023^[118]), Korea is

particularly vulnerable to disruptions affecting the flow of inputs, components and finished products across international markets.

Box 3.16. Challenges related to Korea's aging labour force

Korea's aging population presents significant challenges for SMEs, primarily due to the rising average age of SME leadership and a shrinking pool of workers willing to engage in manufacturing roles. In 2023, the average age of CEOs of SMEs in Korea was 55.3 years, continuing an upward trend from 51.3 years in 2012 and 54.1 years in 2018 (KOSIS, 2023^[119]). With the average retirement age in Korea at 63 years (Korea Institute of Public Finance, 2023^[120]), a substantial proportion of SME leaders are nearing retirement, potentially leading to a wave of business closures or liquidations. A survey conducted by KOSIS in 2022 revealed that 37% of SME owners over 55 plan to retire within the next five years, and 60% of these owners intend to liquidate their businesses rather than invest in innovation.

Moreover, the country is grappling with a declining labour force. Korea's total working-age population (aged 15-64) is projected to decrease by 12% by 2030, with the manufacturing sector anticipated to be one of the most affected areas (KOSIS, 2023^[119]). This labour shortage is intensified by geographic preferences, as 72% of the population between the ages of 20 and 39 prefer living in the Greater Seoul area, which houses 50% of Korea's population but only 24% of its SMEs (KOSIS, 2023^[119]). According to a survey by the Korean Chamber of Commerce in 2022, 68% of SMEs located outside of Seoul face difficulties in running their business from diminishing non-metropolitan population with 51% attributing this challenge to the reluctance of young people to relocate from the capital (Korea Chamber of Commerce and Industry, 2022^[121]).

The shortage of highly skilled labour necessary for digital transformation further exacerbates these challenges. Only 9.7% of SMEs have implemented educational programs related to digital skills, and 84.0% lack a dedicated data analytics specialist (TIPA, 2022^[122]). This trend further limits the talent pool available for digitally oriented manufacturing roles, complicating efforts by SMEs to modernise and adapt to new technological demands.

The key to addressing the challenge of an aging population lies in boosting productivity to compensate for the shrinking working-age population and ensuring a successful transfer of businesses to the younger generation. However, this is a complex issue, largely due to the shortage of skilled labour, which exerts upward pressure on wages. As a result, many SMEs struggle to attract the talent necessary for advancing production methods and adopting new technologies. The high cost of labour further discourages investment in workforce development, creating a cycle where SMEs are unable to innovate and increase productivity at the pace required. This labour shortage is particularly acute in sectors such as manufacturing, where digital skills and technological expertise are increasingly essential to maintain competitiveness. Without sufficient human resources, the productivity gains needed to offset demographic decline remain out of reach, exacerbating the economic challenges posed by Korea's ageing population.

Manufacturing SME readiness

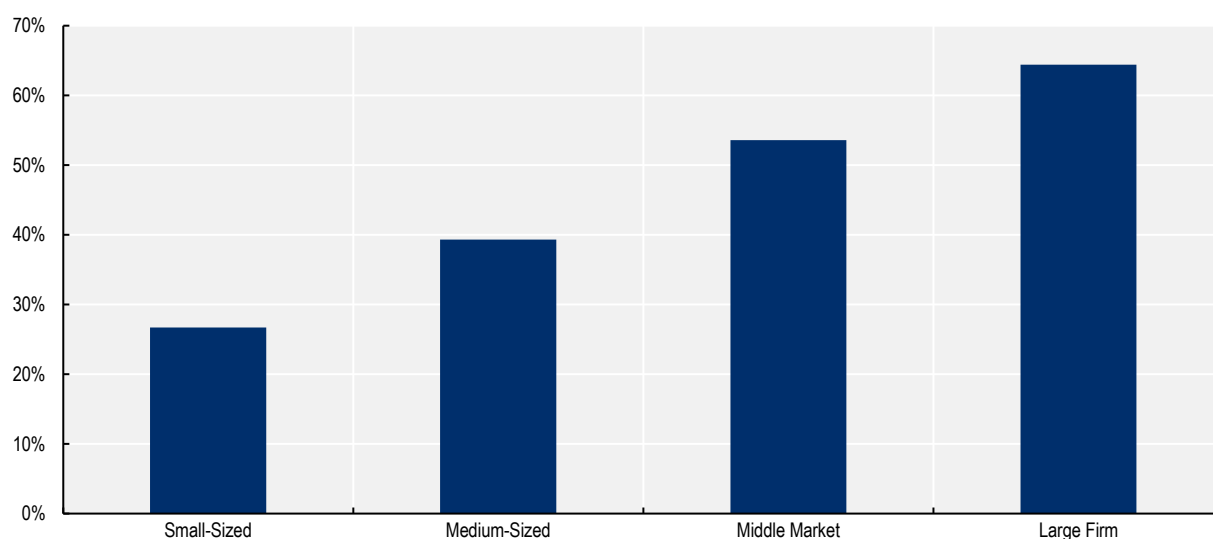
Industry 4.0: Data and Digital Readiness of Firms

A significant proportion of firms in Korea lack the necessary infrastructure for data management and analytics. According to the 2022 SME Informatisation Level Survey, 41.4% of firms do not have a system for collecting and storing data in Data Collection and Sharing. Additionally, 22.6% of firms collect data but do not share it with others, while 36.1% of firms share at least some data. In terms of Data Analytics

Capability, 84.0% of firms do not employ any data analytics specialists, and only 9.7% provide some form of training for staff in data analysis. Only 6.3% of firms allocate resources to analysing the data they collect. Reflecting this lack of data-related capabilities, 72.6% of firms do not have a strategy for transitioning to smart manufacturing processes (TIPA, 2022^[122]). These figures underscore the challenges Korean firms face in adapting to Industry 4.0, particularly in areas related to data management, analytics, and the adoption of smart manufacturing technologies. Human resources remain a key limitation in this transition, with skilled labour in high demand, and jobs in less desirable locations often dissuading workers from joining manufacturing firms, which are frequently located far from the capital. This is particularly problematic for smaller size firms as the trend towards digital transformation is far better amongst Large or Middle Market firms compared to Small-Sized firms as shown in Figure 3.17.

Figure 3.17. State of implementation of digital transformation measures by business size

As a share of businesses that have implemented or plan to implement digital transformation measures by size (%)



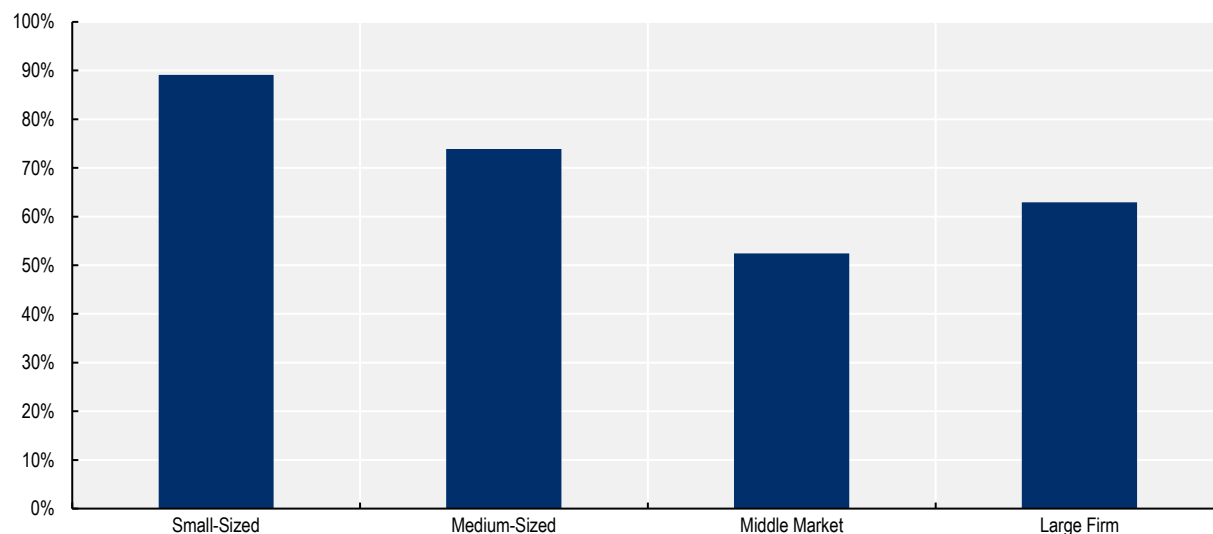
Source: (TIPA, 2022^[122])

Decarbonisation and energy efficiency

SMEs in Korea face considerable challenges in adopting measures to reduce greenhouse gas emissions. In the manufacturing sector, 89.1% of small firms and 52.4% of mid-sized firms have not implemented any strategies to lower energy consumption or decrease their carbon footprint as illustrated in Figure 3.18. Similar to the barriers observed in the adoption of Industry 4.0 technologies, many firms lack the tools and capabilities needed to measure and monitor emissions effectively. In addition, SMEs have historically faced limited incentives and regulatory pressure to track their environmental performance. This underscores the need for greater awareness, technical support and capacity-building efforts to help SMEs respond to evolving sustainability requirements and contribute to Korea's emissions-reduction objectives. The challenge is further compounded by limited access to public support measures, such as incentives for energy-efficiency investments and specialised technical assistance.

Figure 3.18. Businesses not taking steps to reduce their carbon footprint or energy consumption by size

As a share of businesses implementing measures to reduce their energy consumption or carbon footprint by business size.



Source: (STEPI, 2022^[123])

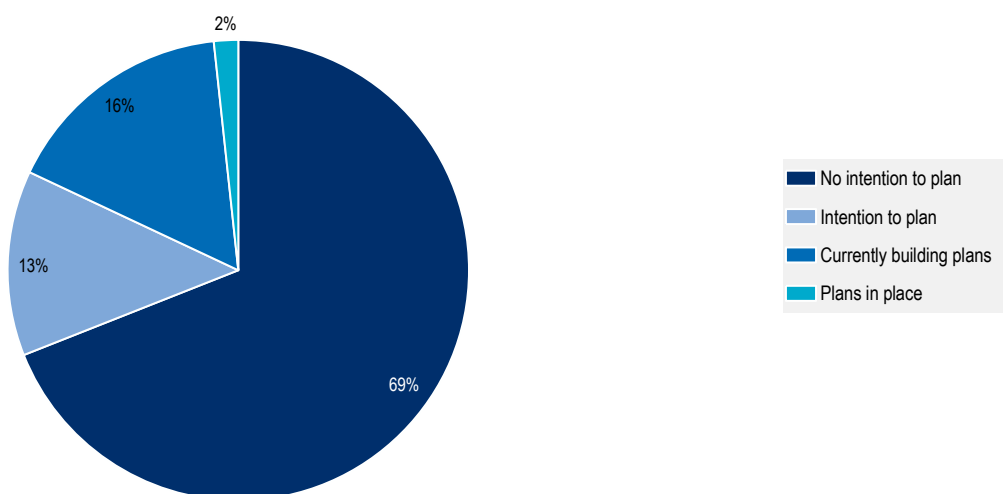
Supply Chain Readiness

Many SMEs in Korea are unprepared to address potential supply chain disruptions that could halt production. According to the 2022 KOSME Survey, among 126 firms that reported a severe or very severe negative impact from global supply chain disruptions, 50% identified raw material procurement as their most significant challenge, followed by logistics delays at 19.8% (KOSME, 2023^[124]). Regulatory barriers around raw material procurement and the concentration of supply from specific countries exacerbate these issues. Many Korean firms are heavily reliant on single supplying country due to competitive pricing from dominant countries, which leaves them vulnerable to external shocks. For instance, out of the ten electronic parts that are imported with reliance on single country of over 40% and USD 10 million revenue, the reliance on China ranges from 76.7% to 96.8% for the top five imported parts for the electronics industry (Bank of Korea, 2023^[125]).

Over-reliance on single-country suppliers, especially in sectors like electronics, automotive, and chemicals, poses a considerable risk. For instance, Korea's dependence on imports of key components from China exposes SMEs to geopolitical tensions and market volatility (Bank of Korea, 2023^[125]). Furthermore, many SMEs lack formal risk management strategies, with only a small proportion having contingency plans in place to diversify suppliers or secure alternative sources. As global supply chains become increasingly fragile due to factors such as the COVID-19 pandemic and geopolitical conflicts, the need for SMEs to enhance supply chain resilience through diversification, stockpiling or digital supply chain monitoring has become more urgent. However, a lack of awareness and resources, combined with the complexity of navigating trade regulations, has left many firms ill-equipped to adapt. Survey results show that only 2% of Korean firms indicate they are prepared to handle supply chain disruptions (Figure 3.19).

Figure 3.19. Supply chain disruption readiness

As a share of surveyed businesses indicating their current preparation status for a potential supply chain disruption



Source: (KOSME, IIT and KITA, 2024^[126])

Government policy (automotive, machinery and electronics)

To respond to these industrial megatrends, the Korean government has set ambitious targets for the coming decades. The 2050 Carbon Neutrality and Green Growth Commission, established in 2021, brings together government representatives and civilian experts to co-ordinate efforts to reduce greenhouse gas emissions. Its near-term objective is to reduce emissions by 40% by 2030 relative to 2018 levels, drawing on a combination of direct emissions reductions, carbon absorption measures and international mitigation efforts.

With regard to the digital transformation, the I-KOREA 4.0 policy framework, which promotes the integration of new technologies into the industry, has evolved into the Presidential Committee on Digital Platform Government in 2022. This initiative focuses on leveraging AI and data analytics to support firms in their digital transformation efforts.

To enhance supply chain resilience, the MPE (Materials, Parts and Equipment) Competitiveness Committee aims to strengthen domestic production and supply chains under the Industry Supply Chain 3050 Strategy. The primary objective is to reduce reliance on any single country for critical parts to less than 50%, thereby mitigating risks associated with global supply chain disruptions.

Future of Korean Manufacturing Innovation 3.0

Launched in 2014, Manufacturing Innovation 3.0 marked Korea's first major strategy for modernising its manufacturing sector and preparing it for the global shift towards Industry 4.0 (MOTIE, 2015^[127]). The policy aimed to integrate advanced digital technologies, focusing on the adoption of smart factories, automation, and the Internet of Things (IoT). It sought to drive productivity, reduce costs, and enhance the competitiveness of Korean manufacturing in global markets.

The core objective of Manufacturing Innovation 3.0 was the digitalisation of manufacturing processes across industries. By encouraging the use of IoT, big data, and cloud computing, the strategy aimed to optimise production, enable real-time data-driven decision-making and automate repetitive tasks. A key element of the policy was the development of smart factories, which rely on interconnected systems and

data to automate manufacturing, reduce reliance on manual labour and improve efficiency (MOTIE, 2015^[127]).

In particular, the policy emphasised supporting SMEs in adopting these new technologies. The government established financial assistance programs and provided technical guidance to help businesses integrate smart factory models into their operations. One of the main initiatives under this strategy was the Smart Factory Propagation Program, which was designed to help manufacturers develop digital and automated production lines through the use of model factories (MOTIE, 2015^[127]).

Although this top-down approach was largely unsuccessful due to weak take-up from the firms due to high cost and lack of knowledge in its implementation, the policy laid the foundation for subsequent digital strategies such as I-KOREA 4.0 and the Digital New Deal. By focusing on the adoption of advanced technologies like AI and robotics, Manufacturing Innovation 3.0 played a role in positioning Korea as a leader in Industry 4.0. Its goals were further expanded in later policies, which continued to build on the need for smart factory infrastructure, digital transformation and technological innovation in manufacturing.

I-KOREA 4.0

Launched in 2017, I-KOREA 4.0 is Korea's overarching policy framework guiding the nation's transition to the Fourth Industrial Revolution, similar to Germany's Industry 4.0. I-KOREA 4.0 emphasises key elements of Industry 4.0, such as big data, AI, and cloud computing, encapsulated in the concept of D.N.A. (Data, Network, AI). The policy aims to expand the use of data by enhancing resource availability and establishing model smart factories to boost productivity and accelerate digital transformation (MSIT, 2017^[128]).

Key measures under this initiative include expanding medical data infrastructure, incentivising smart factory construction, regulating autonomous vehicles and reforming policies related to SME-Venture capital startups. Additionally, the government has enacted legislation on the use and protection of information, such as the Act on Promotion of Information and Communications Network Utilization, the Personal Information Protection Act, and the Credit Information Use and Protection Act. These laws provide the legal framework necessary for firms to utilise data effectively, gaining valuable insights for supply chain optimisation (MSIT, 2017^[128]).

Digital New Deal

Introduced in 2020 as part of the Korean New Deal, the Digital New Deal drove Korea's shift into the Fourth Industrial Revolution by promoting digital transformation across various sectors. It focuses on key technologies such as AI, big data, 5G and cloud computing, highlighting the importance of data in conducting the transition to new technology. Additionally, the policy includes the development of digital healthcare, smart cities and AI education. These advancements are supported by legislation that governs data protection and the use of information, enabling firms to use data effectively. The Digital New Deal is backed by KRW 58 trillion (approximately USD 48 billion), with investments directed toward AI-powered industries, data infrastructure and digital startups to foster innovation and job creation across the economy (MOEF, 2017^[129]). The Korea AI Manufacturing Platform (KAMP) was launched one year later in 2021 to help accelerate the adoption of artificial intelligence (AI) in the manufacturing sector (Box 3.17).

However, some shortcomings of this policy are related with limited data collection, unequal sectoral benefits, worsened regional disparities, infrastructure gaps and human resource development. Ultimately, SMEs still lacked the targeted support they required that would fill the gap in technical guidance. These aspects were noted and improved upon in MIDAS 2027.

Box 3.17. KAMP: The Korea AI Manufacturing platform

The Korea AI Manufacturing Platform (KAMP), launched in 2021, was designed to promote AI utilisation and manufacturing data analysis among SMEs in the manufacturing. With over 25 000 Smart Factories constructed, the keystone to harnessing the technological advancements into production is to utilise the production data for analysis. Through the introduction of Smart Factories, productivity increased by 28.5%, product quality increased by 42.5%, revenue increased by 7.4% and delivery date compliance increased by 16.4% (MSS, 2021[23]). However, harnessing the data and training the AI is expected to further increase these figures through three main channels: quality control, preventive maintenance and autonomous operations. To support this initiative, KAMP provides 50 types of manufacturing AI datasets and 13 AI analysis support tools, facilitating data and AI usage among manufacturing SMEs. The platform has achieved a total of 46,000 dataset downloads, driving increased AI usage within the sector.

Defective product prediction using AI-based SMT process data

In the semiconductor industry, PJ Electronics commissioned a project with Brique to reduce errors and improve the efficiency of Surface Mount Technology (SMT). The goal was to enhance failure rate prediction and optimise their existing small-volume, high-variety production process. Many outsourcing companies face similar challenges, managing low-quantity, high-variety production for multiple clients, making optimisation through failure prediction essential to lowering costs. By training their data with artificial intelligence (AI), PJ Electronics reduced data analytics time from eight man-hours to 40 seconds, achieving 98.53% accuracy. Instead of relying on manual sampling for quality control, their production process can now be optimised without delay when failures occur (KAMP, 2023[24]).

Development of an AI model to predict when to change cutting tools

In the machinery sector, Dongpyeong Tech partnered with NSmarts to optimise production through preventive maintenance. Milling machinery represents a significant cost factor, as wear and tear necessitate machinery replacement. Previously, expert operators used intuition and experience to decide when to replace equipment. However, less experienced operators often mistimed these judgements, leading to increased costs from damaged raw materials. By installing Manufacturing Execution System (MES) data recording equipment, the project harnessed vibration data to train AI models. This led to an increase in production per machine from 200 to 258 units and reduced costs by 22.8%, demonstrating the value of preventive maintenance (KAMP, 2023[25]).

Both use cases highlight the key advantage of AI in supplementing or replacing expert operators in the production process. As discussed in earlier section, the manufacturing workforce is nearing retirement, and the loss of their know-how risks reducing productivity in the sector. AI-trained models, built through manufacturing data analytics, can replicate this expertise, filling the gap left by experienced staff who previously relied on intuition and experience to calibrate procedures.

However, a key limitation of the Korea AI Manufacturing Platform (KAMP) is the scarcity of available data. While KAMP offers data to new analytics firms for AI model training, the market for data is not fully developed. This stems largely from concerns over firms' data sovereignty, closely tied to their production know-how. The valuation of data and analytics services remains uncertain, and significant shifts in perception will be required to create an active marketplace.

MIDAS 2027 (Manufacturing Innovation and DX Acceleration Strategy)

Launched in 2023, MIDAS 2027 focuses on transforming the manufacturing sector, particularly SMEs. This strategy is aligned with broader digital transformation goals but specifically targets manufacturing by

accelerating the adoption of Industry 4.0 technologies like AI, digital twin systems and automated robotics. One of its main goals is to create 25,000 digital manufacturing companies by 2027. To achieve this, the KOSMO offers financial and technical support to SMEs, helping them adopt automation, AI and other advanced technologies. The government has allocated KRW 218 billion (around USD 180 million) for these efforts, promoting automation through robotics and establishing a data ecosystem that enhances production optimization. MIDAS 2027 aims to improve productivity by advancing digital capabilities with a focus on data standardization across manufacturing processes (MSS, 2023^[130]).

The evolution of Korea's manufacturing policy reflects a structured approach to promoting digital transformation, especially for SMEs. Initially, Manufacturing Innovation 3.0 and I-Korea 4.0 laid the groundwork for smart factory models, providing a standardised template that firms were encouraged to follow. However, while these policies defined the ideal digitalised production framework, they faced challenges in broad adoption. SMEs in particular, struggled due to a lack of financial resources, data infrastructure, and skilled personnel, which hindered their ability to transition to the new technologies.

The Digital New Deal built on this by creating the data infrastructure necessary for firms to begin optimising their production processes. It provided broader access to digital tools and facilitated the use of big data in manufacturing. However, while the availability of data improved, the transformation process remained uneven, with many SMEs still unable to fully utilise the technologies at hand.

With MIDAS 2027, the government is now addressing these challenges by offering tailored support to firms. This policy focuses on accommodating the specific needs of different production procedures, allowing for a more flexible transition to smart manufacturing (MSS, 2023^[130]). This approach is designed to ensure that both financial assistance and technical guidance are aligned with the unique circumstances of each firm, particularly those of SMEs, which were underserved by earlier policies.

In this way, MIDAS 2027 marks a shift toward a more adaptive and targeted strategy, aiming to resolve the gaps identified in previous initiatives and accelerate the digital transformation of Korea's manufacturing sector.

Smart Manufacturing Innovation Support Programme

As the key element of MIDAS 2027, the KOSMO, operating under the Technology Innovation Promotion Agency (TIPA), plays a crucial role in supporting SMEs in their transition towards advanced technologies, including Industry 4.0 (MSS, 2024^[131]). The programme's budget stands at KRW 218 billion.

This initiative strategically positions firms with strong DX capabilities to progress towards implementing AI and digital twin technologies, while simultaneously supporting firms that are struggling with the basic stages of digitalisation. The models used in this programme are tailored to different categories, ranging from cross-industry models to those aligned with carbon-neutral industries. The programme also promotes automation, particularly through the use of manufacturing robotics (MSS, 2024^[131]).

A significant aspect of this initiative is its aim to establish a manufacturing innovation infrastructure and a data ecosystem that enables analytics and production optimisation. These efforts are expected to boost productivity and fully harness the potential of Industry 4.0, AI and Big Data (MSS, 2024^[131]) - areas where the manufacturing sector has traditionally been underdeveloped.

Semiconductor Mega Cluster

To strengthen its high-tech industry, Korea is establishing a Semiconductor Mega Cluster in Yongin, near the capital, aimed at securing USD 465 billion in private investment. The cluster will host 16 fabs, including 13 production and 3 research facilities, focusing on both system and memory semiconductors (MOTIE, 2024^[132]).

The government has passed several laws to support this effort, including the Special Act on the Expansion of the National Power Grid, which fast-tracks construction permits to reduce project timelines by 30%. Additional measures include tax credits to encourage investment and a High-Tech Industry Regulation Index to minimise bureaucratic obstacles.

The policy also aims to address weaknesses in the Korean semiconductor industry, which currently has a supply chain self-reliance rate of 30%, exposing it to global supply chain risks. The cluster is expected to boost the parts industry, aiming to increase self-reliance to 50% by 2030. Further objectives include scaling up AI semiconductors and foundries, with a specific focus on fabless companies supported by USD 18 billion in financial loans and a USD 224 million Semiconductor Ecosystem Fund. The government aims to increase the market share of system semiconductors from 3% to 10% by 2030 (MOTIE, 2024^[132]).

To ensure the availability of skilled labour, three Academia-Industry Liaisons will be established in Pangyo, Suwon, and Pyeongtaek, complemented by AI semiconductor graduate schools and industry-specific R&D and mentoring programs (MOTIE, 2024^[132]).

Carbon Neutral Green Growth National Strategy

Announced in 2023, the Carbon Neutral Green Growth National Strategy is Korea's primary policy for advancing the green transition within the manufacturing sector. The strategy focuses on four main areas: shifting production in energy and goods, promoting green industries and investments, reducing energy consumption, developing climate change infrastructure, and expanding global green Official Development Assistance (ODA). The policy aims to reduce carbon emissions by 45.9% by 2030, reaching a target of 435.6 million tonnes. The largest reductions will come from transitioning energy and industrial production, achieving a combined reduction of 155 million tonnes of carbon (2050 Carbon Neutral Committee, 2023^[133]).

For energy production, Korea plans to expand nuclear power by constructing new plants and increasing the share of renewable energy from 9.2% in 2022 to 21.6% by 2030, supported by the RE100 Fund (USD 224 million) and the formation of RE100 Industrial Complexes. In industrial production, the government will provide incentives for firms to manage energy consumption more effectively, supported by the expansion of Advanced Metering Infrastructure (AMI), Meter Data Management Systems (MDMS), and Energy Management Systems (EMS).

To foster the green industry, the Technology Innovation Fund will match private investments to support green startups, complemented by tax credits for green technology investments. Existing industries will be encouraged to adopt carbon-reducing measures through Contracts for Difference (CCfD) and incentivised carbon emission trading.

Acknowledging the lag in SME transitions, the government offers targeted support through the SME Carbon Neutral Transition Support program, providing up to USD 224 000 for carbon-reducing initiatives, and the Carbon Neutral Smart Factory Formation policy, which provides up to USD 150 000 for upgrading production facilities. The New-Growth Infrastructure Fund also offers loans of up to USD 4.5 million for green technology investments, with a total budget of USD 72 million.

Mobility

As part of the Carbon Neutral Green Growth Strategy, the government aims to expand the supply of electric vehicles (EVs), increasing the market penetration of electric and hydrogen vehicles from 1.7% in 2022 to 16.7% by 2030. The policy includes transitioning industrial vehicles to alternative energy sources such as e-fuel, hydrogen, and electricity, while gradually reducing subsidies for consumers as the supply of EVs increases.

Given the significance of the automotive industry to the Korean economy, the policy also addresses the challenges of transitioning certain supply chain components, such as engines, to electric vehicles. The government aims to support current suppliers in shifting their business focus while recognising that demand for parts will continue in aftermarket and developing markets (2050 Carbon Neutral Committee, 2023^[133]).

SME CBAM Response Infrastructure Support Programme

A key driver prompting firms to take action on environmental issues has been the EU's Carbon Border Adjustment Mechanism (CBAM), which requires companies to provide certification of the carbon emissions associated with their products. In response, MSS has stepped in to offer financial support, assisting firms in certifying the carbon output for each product line and providing consulting services throughout the process. In 2024, MSS supported 110 firms with KRW 1.7 billion worth of services, aiming to ease the financial burden on businesses. This assistance included establishing carbon footprint inventories for each product, verifying them and advising firms on the cross-border carbon taxes they may be subject to. This initiative serves as a prime example of how government policy can effectively address a financial need stemming from an external regulatory shock, enabling firms to better navigate the evolving trade environment (MSS, 2024^[134]).

Industry Supply Chain 3050

Following the passage of new supply chain legislation, Korea aims to reduce reliance on raw materials and parts from any single country to 50% by 2030. This objective will be pursued through three strategies: self-sufficiency, diversification, and materials stocking. The government plans to increase investment in supply chain R&D from USD 7.5 million in 2023 to USD 55 million in 2024, supported by amendments to the Act on Corporate Revitalization, which allows firms to merge for vertical integration to manage supply chain shocks (MOTIE, 2023^[135]).

A dedicated team within the Ministry of Trade, Industry, and Energy (MOTIE) monitors 185 critical materials using Big Data and AI to ensure production continuity. Firms are encouraged to diversify raw material sources through transport cost difference compensation, whereby 50% of additional import costs are covered when sourcing from alternative countries. The budget for key raw material reserves, such as lithium and nickel, has also been significantly expanded from USD 65 million to USD 226 million. This is important for SMEs which often operate on low margins, which are severely impacted by transport costs of raw materials (MOTIE, 2023^[135]).

Table 3.5. Summary of analysed policies in Korea

Investment Plan Name	Specific Initiative (if applicable)	Managing Entity or Organisation	Scope of Implementation	Policy Instrument	Target Group	Allocated Budget	Addressed Megatrend
Manufacturing Innovation 3.0		MOTIE	National	Subsidy	Manufacturing Firms	KRW 1 trillion	Digital
I-Korea 4.0		MSIT	National	Subsidy	All manufacturing SMEs	KRW 2.2 trillion (2018-2022)	Digital
Digital Deal New		MSIT	National	Subsidy/R&D	SMEs, ICT Firms	KRW 6.3 trillion (2020-2022)	Digital
MIDAS 2027	Smart Manufacturing Innovation	MSS	National	Subsidy	Manufacturing SMEs	KRW 218 billion (2024)	Digital

	Support Programme*						
	KAMP: Korea AI Manufacturing Platform	MSS	National	Subsidy	Manufacturing SMEs	KRW 144 billion (2023)	Digital
Semiconductor Mega Cluster		MOTIE	National/Regional	Policy Fund/R&D/Infrastructure	Electronics SMEs	-	Digital, Value Chains
Carbon Neutral Green Growth National Strategy		Ministry of Environment/Green Growth Commission	National	Subsidy/R&D	Automotive SMEs	KRW 89.9 trillion (2023-2027)	Low-carbon transition
Industry Supply Chain 3050		MOTIE	National	Subsidy	Automotive/Electronics SMEs	KRW 73.9 billion (2024)	Value chains
SME CBAM Response Infrastructure Support Programme		MSS	National	Subsidy	SMEs exporting to the EU	KRW 2.4 billion (2024)	Low-carbon transition

Note: This table provides an example of the policies researched by the OECD for this project and does not offer a comprehensive overview of the country's policies in the manufacturing sector.

*Smart Manufacturing Innovation Support Programme includes the budget for KAMP

Source: OECD analysis based on desk research.

Conclusion

Korea's manufacturing SMEs are at a critical juncture, facing both challenges and opportunities as they navigate the complexities of digital transformation, low-carbon transition and supply chain resilience. Despite their pivotal role in the national economy, representing 96.9% of all firms and employing 67% of the workforce in the manufacturing sector, SMEs are struggling to keep pace with evolving global trends.

Government initiatives such as the I-Korea 4.0 policy, the Semiconductor Mega Cluster and the Carbon Neutral Green Growth National Strategy aim to address these gaps. By fostering innovation, investing in infrastructure, and offering targeted support, these policies seek to enhance the competitiveness of Korean SMEs in a rapidly changing global market. Programmes like the KAMP demonstrate the potential of collaborative platforms in driving digital adoption and efficiency gains, while the Industry Supply Chain 3050 strategy outlines a path towards greater self-sufficiency and reduced vulnerability to global disruptions.

However, significant obstacles remain. The aging population of SME leaders, coupled with a shrinking and geographically concentrated labour force, poses a unique challenge. Many SME owners are nearing retirement, with little incentive to innovate, and the lack of skilled labour outside the capital region further constrains growth. Addressing these demographic challenges will require innovative policy approaches, including targeted training programmes, incentives for younger entrepreneurs, and greater support for regional development.

As digitalisation, sustainability requirements and supply chain considerations continue to reshape manufacturing, Korean SMEs will need to strengthen their capacity to adapt and innovate. Public support measures, private-sector investment and co-operation across stakeholders can play an important role in helping SMEs navigate these changes and remain competitive.

United States

Introduction

Like many advanced industrial economies, the United States has seen manufacturing employment decline over the past several decades. Nevertheless, it remains a global manufacturing leader, with manufacturing output continuing to expand in absolute terms. In 2021, U.S. manufacturing value added reached approximately USD 2.5 trillion, representing 15.4% of the global total and exceeding the combined output of Japan, Germany and Korea (World Bank Group, 2024^[136]).

However, these figures do not fully reflect the broader role of U.S. companies in the global industry. Many U.S. companies retain high-value activities such as research, design and product development while relying on international production networks for manufacturing. This is particularly evident in the semiconductor industry, where numerous "fabless" firms specialise in chip design and contract fabrication to external partners. As a result, a substantial portion of their economic activity is not reflected in standard manufacturing statistics. In fact, fabless firms captured USD 153 billion in revenue in 2020, accounting for about one-third of the global semiconductor industry value (Yeung, Huang and Xing, 2023^[137]). In 2020, the U.S. also ranked as the world's fourth-largest steel producer, while in 2021, it was the second-largest automaker and the top exporter of aerospace products (Grabow, 2023^[138]).

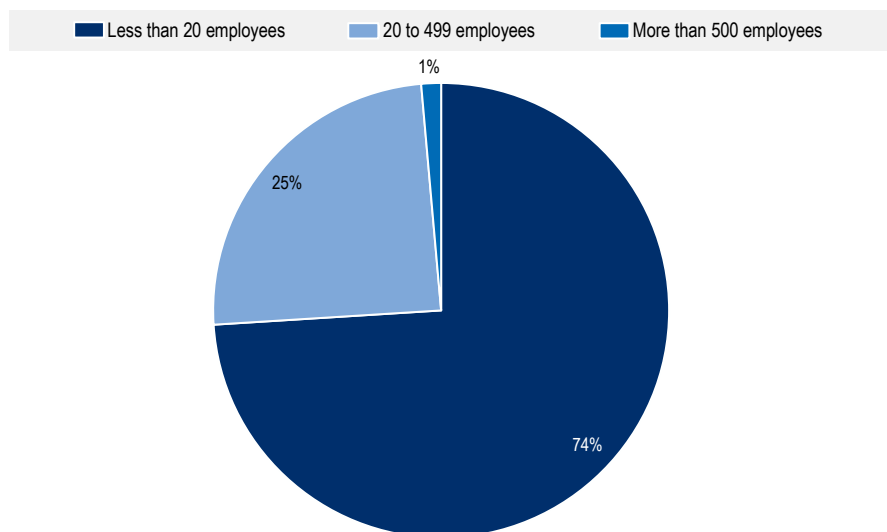
The manufacturing industry is a critical component to the U.S. domestic economy. In 2024, the manufacturing sector added USD 2.91 trillion in value added to the economy, which represents 10% of U.S. GDP, and the value of U.S. manufactured goods exported in 2024 was USD 1.6 trillion (NAM, 2024^[139]; World Bank Group, 2024^[136]). Importantly, manufacturing accounts for 53% of all private-sector R&D in the U.S., which makes the sector a key driver of innovation. In 2022, total R&D spending reached USD 361.2 billion with manufacturers of semiconductors and other electronic components accounting for close to 16%. The automotive sector also contributed significantly, accounting for about 9% of the sector's total spending in R&D. Furthermore, manufacturing supported nearly 13 million jobs in 2025 (NAM, 2025^[140]), with 74% of manufacturing firms having fewer than 20 employees. The average annual earnings for manufacturing employees stood at USD 98 846 and in 2023 (NAM, 2024^[141]).

U.S. manufacturing contributes significantly to global value chains, with a large share of its value added absorbed abroad. According to the OECD-WTO Trade in Value Added (TiVA) 2025 edition, 18.2% of U.S. manufacturing value added in 2022 was absorbed abroad in foreign final demand, compared with an OECD average of 13%. For the economy as a whole, the share was 8.8% in the U.S., above the OECD average of 6.8% (OECD, 2025^[142]). This illustrates that manufacturing generates a large share of the country's internationally traded value added, underscoring its global competitiveness.

However, the U.S. manufacturing industry faces several pressing challenges that could hinder its long-term competitiveness. Chief among them is a persistent struggle to attract and retain skilled talent. According to the 2025 Manufacturing Outlook Survey of the National Association of Manufacturers (NAM), 48% of producers cite talent attraction and retention as their top concern (NAM, 2025^[140]). A 2024 study by Deloitte and the Manufacturing Institute estimates that 3.8 million new manufacturing jobs will be created by 2033, with nearly three-fourths openings expected from retirement. Yet, half of these may go unfilled (NAM, 2024^[139]; Deloitte and the Manufacturing Institute, 2024^[143]). The NAM survey also points to regulatory costs as a major challenge for manufacturers, costs that were estimated to be over 70% higher for manufacturers with fewer than 50 employees .

Figure 3.20. Composition of U.S. manufacturers by size

As a percentage of total manufacturers in the US

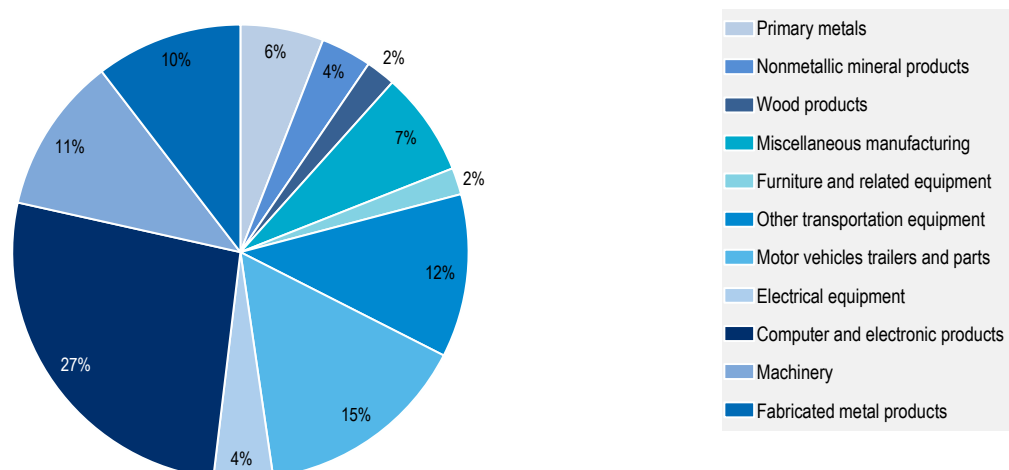


Source: (NAM, 2024^[144]).

The U.S. semiconductor industry is an important driver of economic growth and innovation. As illustrated in Figure 3.21, computer and electronic products were the largest manufacturing subsector in the U.S. in 2023. According to the Semiconductor Industry Association (SIA), U.S. semiconductor sales totaled USD 264 billion in 2023, accounting for 50% of global semiconductor sales, which stood at USD 526.9 billion the same year. The industry directly employs 338 000 people in the U.S., primarily in device manufacturing, but also in machinery manufacturing, design and Electronic Design Automation (EDA). It further indirectly supports nearly an additional 2 million jobs in over 300 downstream sectors (SIA, 2024^[145]). Semiconductors play a critical role in driving innovation across diverse fields, including artificial intelligence, automotive technologies, , and healthcare. To meet rising demand worldwide, with global sales forecasted to reach USD 1 trillion by 2030, new investments by semiconductor companies are rising. In the U.S., R&D investments by semiconductor companies reached USD 50.3 billion in 2023 (SIA, 2024^[145]). The U.S. plays a major role in the front-end design phase of semiconductor manufacturing process, with key players such as Intel, AMD, Nvidia, Qualcomm, and Texas Instruments. Nevertheless, the industry also relies strongly on global supply chains for materials and components, with significant dependency on Asia for certain manufacturing and assembly processes. For instance, while the U.S. fab capacity is expected to increase by 203% in 2032 compared to 2022, well ahead of Europe's at 124%, China's is expected to increase by 365% in the same period (SIA, 2024^[145]).

Figure 3.21. Composition of value added for durable goods by type in the U.S. manufacturing sector

As a percentage total value added



Note: Calculations by the author. Original figure presented value added for durable goods by type in billions of chained dollars (2008-2022)
Source: (NIST, 2023^[146])

Manufacturing SME readiness

Digital transformation

U.S. small and medium-sized manufacturers increasingly recognise the strategic importance of technological advancement. Yet, high IT infrastructure costs and workforce skill requirements continue to present significant obstacles. To better understand these challenges, the Manufacturing Institute conducted two surveys in February and September 2021, focusing on how SME manufacturers responded to the aftermath of the COVID-19 pandemic and the impact of disruptive technologies. The February survey revealed that 43.9% of SME manufacturers viewed technology adoption as critical to their growth, while over 77% were investing in technology to reduce production costs. Additionally, 73.4% reported investing to improve operational performance. However, talent shortages remain a major barrier: 77% of surveyed SMEs indicated they were struggling to identify and retain skilled workers, underscoring the need for workforce development alongside digital transformation (Manufacturing Institute and BKD, 2021^[147]).

By September 2021, the Manufacturing Institute's follow-up survey revealed growing momentum among SMEs in adopting disruptive technologies. Among businesses investing in these technologies, 64.3% reported improvements in production efficiency and flexibility. Overall, one in three respondents had accelerated their investments, signalling a shift toward more proactive digital transformation strategies. Of those accelerating investments, 61.4% cited enhanced operational performance as the primary driver, suggesting that SMEs increasingly view disruptive technologies as essential tools for staying competitive in a rapidly evolving market landscape (Manufacturing Institute and BKD, 2021^[148]).

Economic shocks and supply chain disruptions

The U.S. manufacturing sector, including SMEs, was significantly affected by the global semiconductor shortage and supply chain disruptions triggered by the COVID-19 pandemic. These challenges reflected a broader global trend, and were compounded by geopolitical tensions, rising raw material and energy

costs, and persistent labour shortages, all of which contributed to production volatility. Around the world, SMEs faced heightened difficulties due to their limited flexibility and bargaining power compared to larger firms (OECD, 2023^[149]). Some U.S.-based manufacturers relocated production to Mexico and Asia (Gantz, 2024^[150]; Van Wyck et al., 2023^[151]), with cost pressures such as structural energy costs likely contributing to those decisions (The Manufacturing Institute and KPMG, 2020^[152]; NAM, 2025^[140]). For example, the production of EV components, particularly batteries, has increasingly shifted to Asia due to cost advantages and the established infrastructure in the region (Bhutada, 2023^[153]; Verpraet and Harrison, 2021^[154]; BCG, 2024^[155]). At the same time, supply chain reconfigurations generate opportunities for SMEs in regions benefiting from nearshoring, as well as for firms that are able to innovate and adapt to evolving production and market dynamics.

Trade uncertainties and supply chain disruptions remained a major concern for U.S. manufacturers in 2025. According to the National Association of Manufacturers Outlook Survey for the fourth quarter of 2025, 73% of surveyed firms identified trade uncertainties as one of their main business challenges, while 30% cited supply chain challenges, and 59% indicated increased raw material costs (NAM, 2025^[156]).

Low-carbon transition and resource efficiency

SME manufacturers in the United States continue to face significant barriers to operational change that promotes resource efficiency. Escoto, Gebrewot and Morris (2022^[157]) reviewed assessments from the American Society of Mechanical Engineers (ASME) and Indiana University to examine the challenges facing U.S. SME manufacturers in adopting low-carbon and energy efficient processes and improving performance. Their analysis identifies three main types of barriers: strategic alignment barriers, where changes related to the low-carbon transition are perceived as misaligned with short-term business growth and customer demands; financial barriers, as investments in new technologies and methods are often judged to have uncertain returns; and organisational barriers, as many SMEs lack the structure, skills, or resources needed to implement and maintain operational changes. Based on historical data, the study suggests that investment in low-carbon technologies and practices, especially when supported by recognised standards such as ISO or ASTM, was associated with improved returns on investment and higher sales among SMEs, including smaller manufacturers

Beyond the organisational and financial hurdles, U.S. SME manufacturers face skills-related barriers to implement more resource-efficient processes and benefit from changes in manufacturing markets. Recent evidence by LinkedIn shows that the U.S. trails behind other auto manufacturing countries in EV skill development, with only 3.7% of auto workers having EV-related skills, roughly half the rate observed in the UK (LinkedIn, 2023^[158]).

SMEs are increasingly exploring low-carbon and resource-efficient manufacturing practices, as a means of improving productivity, reducing operating costs and strengthening competitiveness. Evidence also points to potential benefits in areas such as product quality, organisational performance and supply-chain management (Escoto, Gebrehewot and Morris, 2022^[157]; EPA, 2024^[159]). To support implementation, some SMEs have engaged in partnerships and collaborative initiatives, while firms with greater financial resources or access to external support have invested in measures such as energy-efficiency improvements and the use of recycled materials. Nevertheless, uptake remains uneven, reflecting differences in financial resources, technical capabilities, access to technology and the availability of external support (Jamwal et al., 2025^[160]; Prasannath, Maniam and Sundaresan, 2024^[161]; Suchek and Franco, 2024^[162]).

Government policy (automotive, machinery and electronics)

In recent years, U.S. government policies related to the manufacturing industry have been shaped in part by increased global competition. The noticeable shift in production overseas has led to a renewed focus on revitalising the manufacturing industry (Adler and Bonvillian, 2023^[163]). Recent policy initiatives have

focused on supporting domestic manufacturing and strengthening industrial capabilities. Support for such effort has been particularly visible in regions with a long industrial history, including the so-called “Rust Belt” states (Brownstein, 2024^[164]).

The notable increase in industrial policy measures, including major legislation providing direct support to the manufacturing sector, reflects a shift in the overall policy approach towards industry. Historically, the U.S. has relied largely on market-oriented frameworks with limited direct intervention in manufacturing (Adler and Bonvillian, 2023^[163]). The recent emphasis on targeted support therefore signals a broader reorientation in industrial policy and responds to megatrends such as digitalisation, geopolitical considerations, and resource efficiency. This section provides a broad overview of these policy measures and discusses their implications for SMEs. The section illustrates mainly policy initiatives implemented over 2022-24, referencing reviews, adjustments or phasing out adopted or announced in 2025-26.

The CHIPS Act

The CHIPS and Science Act for America was enacted in 2022. Since 2025, its implementation has been subject to review and adjustment, which includes changes in governance and implementation of programmes as well as the renegotiation of some of the grants in place.

While primarily supporting large-scale semiconductor investments, the initiative was also expected to benefit SMEs indirectly through supply chain opportunities and participation in innovation activities. The CHIPS Act’s initial provision included USD 39 billion in incentives for manufacturing facilities, aimed at constructing, expanding, and modernising semiconductor production sites. This encompassed both advanced “front-end” fabrication and “back-end” packaging technologies (CRS, 2023^[165]; CRS, 2023^[166]). The Act allocated USD 2 billion to semiconductor or semiconductor manufacturing equipment manufacturers to produce “legacy” chips, which are widely used in machinery and automotive sectors (e.g., in vehicle systems), and remain critical for everyday operations. The funding was therefore aimed to develop stable supply chains for critical components (The White House, 2022^[167]).

The Regional Technology and Innovation Hubs (“Tech Hubs”) programme was established by the CHIPS and Science Act to strengthen U.S. capacity in key technology areas. The programme, authorised by the U.S. Congress in 2022, aims to foster collaboration between businesses of all sizes, research institutions, non-profit organisations, Tribal communities, labour unions, and state and local governments. In October 2023, the U.S. Department of Commerce designated 31 Tech Hubs across 32 states and territories. These consortia were eligible to compete for implementation grants of up to USD 75 million to expand innovation ecosystems, build supply-chain resilience, and create jobs²⁷. A core objective was to broaden participation in advanced technology sectors so that firms, including SMEs, can benefit from improved access to R&D, partnerships, and workforce development opportunities regardless of location. Notably, 75% of the tech hubs aim to support underserved or rural communities (Buttle, 2024^[168]; The White House, 2023^[169]). Box 3.18 expands on the activities of some of these Tech Hubs and their relevance for SMEs.

Box 3.18. Regional Technology and Innovation Hubs (Tech Hubs)

The **Tech Hubs** funded under the CHIPS Act aim to foster collaboration among private companies, academic institutions, and state and local governments, particularly in underserved regions.

The Tulsa Tech Hub, led by Tulsa Innovation Labs in Oklahoma, focuses on advancing secure autonomous systems in industries like agriculture, pipeline inspections, and transportation. The Tech Hub seeks to strengthen economic and national security while linking small manufacturers to the autonomous systems supply chain. It received grant funding to implement six key projects, including commercialisation strategies among universities and the startups, testing environments, workforce training, and AI development (EDA, 2026^[170]).

The Ocean Tech Hub, led by the Rhode Island Commerce Corporation, aims to advance maritime technologies, focusing on AI-enabled robotics and sensors. Serving Massachusetts and Rhode Island, it leverages the region's coastal assets, including seven commercial ports, to meet the growing demand for ocean technology testing and commercialisation. It aims to provide growth-ready startups and legacy manufacturers with technical assistance and access to capital, helping them participate in and serve the ocean technology market. This includes offering resources like co-working spaces, fabrication labs, and access to ocean testing sites (EDA, 2023^[171]).

CHIPS for America programmes also incorporated measures to support the participation of SME manufacturers in regional semiconductor clusters. Among these were support services delivered through the Manufacturing Extension Partnership (MEP), which provided assistance on technical requirements, business needs and workforce training (NIST, 2022^[172]; Congress.gov, 2022^[173]). The scope and delivery of these support services have been subject to change since 2025.

The Small Business Innovation Research (SBIR) program and the Small Business Technology Transfer (STTR) program provide funding to SMEs engaged in R&D for innovative technologies. By supporting the development and commercialisation of new solutions, these programmes contribute to technological advancement and digital transformation across a range of industries, including semiconductors (U.S. Department of Commerce, 2024^[174]; NIST, 2024^[175]).

The Advanced Manufacturing Investment Credit offers a 35% federal income tax credit for companies investing in semiconductor manufacturing equipment. Enacted under the CHIPS Act, the credit is available to manufacturers of semiconductors and semiconductor manufacturing equipment within the United States that meet certain eligibility requirements. This mechanism can also serve smaller manufacturers by helping offset the capital costs of upgrading their manufacturing lines (IRS, 2024^[176]). Under the One Big Beautiful Bill Act (OBBBA), the tax credit was raised from 25% to 35% for all properties placed into service after December 31, 2025. For domestic manufacturing businesses, the OBBBA also allows a full 100% deduction of research and experimental expenditures, including previously unamortised costs. In addition, eligible small business taxpayers may amend prior-year tax returns to retroactively claim these deductions.

The Inflation Reduction Act (IRA) and the One Big Beautiful Bill Act (OBBBA)

The Inflation Reduction Act (IRA) was signed into law in 2022 with the aim to support domestic energy production, investments in clean energy, deficit reduction, healthcare, and tax reform. This act targeted the decarbonisation of the U.S. economy and aimed to reduce dependency on foreign supply chains (The White House, 2023^[177]). The IRA's provisions included specific measures targeted to SMEs, particularly in the automotive, electronics, and machinery sectors. The One Big Beautiful Bill Act (OBBBA), signed in July 2025, has fundamentally reshaped the clean-energy and industrial-policy provisions of the IRA,

accelerating repeal schedules, compressing qualification deadlines for remaining projects, and imposing new rules barring access to IRA credits for entities linked to certain foreign countries.

Automotive sector

The IRA included tax incentives to accelerate the transition to electric vehicles, such as the Section 45W Commercial Clean Vehicle Credit. This provision allowed businesses, including smaller firms, to claim up to 30% of the purchase cost of qualified electric and fuel-cell commercial vehicles, with caps of USD 7 500 for light duty and USD 40 000 for heavy duty vehicles up to September 2025 (The White House, 2023^[177]).

The Act introduced tax incentives for the use of U.S.-sourced materials, including batteries for EVs and components for EV infrastructure (U.S. Department of the Treasury, 2024^[178]). By creating additional demand for locally manufactured parts, the policy was expected to support SMEs involved in producing automotive components, including electric motors and battery modules.

Electronics

The IRA introduced measures intended to support domestic manufacturing in the energy and electronics sectors. Among these, the Advanced Manufacturing Production Credit provided incentives for the U.S. production of components used in renewable energy technologies, including solar panels, wind turbines, batteries and critical minerals processing. The credit was relevant to manufacturers across these supply chains, including SMEs. Many of the incentivised technologies also rely on advanced semiconductors, linking the measure to demand for components used in applications like energy infrastructure or smart grids (Crux, 2024^[179]; The White House, 2023^[177]). Subsequent legislative changes under the One Big Beautiful Bill Act (OBBBA) modified some of these provisions, including by accelerating the phase-out of support for certain technologies and introducing restrictions related to prohibited foreign entities.

Machinery sector

The IRA established the Clean Energy and Sustainability Accelerator, a financing mechanism intended to support clean-energy deployment through state and local institutions. The initiative was designed to prioritise investment in underserved and disadvantaged communities through distributed-energy technologies such as heat-pumps, community solar and EV charging infrastructure, which may have required specialised manufacturing equipment and installation machinery. Subsequent changes under the One Big Beautiful Bill Act repealed or shortened most credits and incentives that would have fed capital into the Accelerator framework.

The Infrastructure Investment and Jobs Act

The Infrastructure Investment and Jobs Act, also known as the Bipartisan Infrastructure Law (BIL) was signed into law in November 2021. The law's provisions aimed to modernise transportation systems, enhance disaster management capabilities, and develop clean energy infrastructure, while closing the digital divide. Since 2025, implementation of some climate-, clean-energy- and EV-related provisions has been subject to review and adjustment.

The law also aimed to reinforce domestic manufacturing competitiveness and strengthen supply-chain resilience, notably by expanding U.S. capacity in battery materials and critical-minerals processing. Federal initiatives included nearly USD 1 billion in new DOE funding for critical-minerals production, processing and recycling. In 2026, the US administration launched Project Vault, a USD 12 billion public-private strategic critical minerals reserve designed to strengthen supply-chain resilience and mitigate disruptions in access to critical raw materials.

These measures have relevance to SMEs in the automotive, electronics, and machinery sector, as they influence their operations both directly and indirectly, through access to critical components, as well as federal contracts, new market opportunities, and investment in innovation.

The Automotive sector

The BIL included a major USD 7.5 billion investment to develop a national EV-charging network and supported the federal goal of deploying 500 000 public EV chargers by 2030 (U.S. Department of Transportation, 2022^[180]). The expansion of charging infrastructure has implications for a range of economic activities involving SMEs and larger firms alike, including the manufacturing, installation and maintenance of charging equipment, as well as grid-integration services. It may also influence demand across the broader electric mobility value chain, including demand for components, batteries, power electronics and EV-related software solutions.

Electronics sector

The BIL included a USD 65 billion investment in broadband infrastructure to expand digital connectivity across the United States. The deployment of broadband networks involves a range of activities, including the production and installation of network equipment, routers and fibre-optic technologies, in which SMEs participate (U.S. National Telecommunications and Information Administration, 2025^[181]). In addition, investments in grid modernisation rely on technologies such as advanced sensors, automated control systems and battery storage, creating demand for electronic components and related services supplied by firms across the value chain, including SMEs.

Machinery sector

The BIL allocated USD 110 billion for roads, bridges and major infrastructure projects, to upgrade the U.S. transport network. These investments were expected to increase demand for construction machinery such as excavators, cranes and paving equipment (The White House, 2021^[182]). The associated demand for machinery, components and technical services may affect firms operating in these markets, including SMEs. Additional investments in public transit, rail, airports and other infrastructure assets were also expected to increase activity in sectors supplying equipment, components and related support services.

Additional government services available to manufacturing SMEs

Manufacturing USA is a network of public-private Manufacturing Innovation Institutes, established in 2014. These institutes focus on advancing digital manufacturing technologies by bringing together academia, industry, and government. SMEs are encouraged to participate, gaining access to cutting-edge innovations in areas such as advanced materials, smart manufacturing, and digitalisation. Through these collaborations, SMEs can improve their production processes and reduce costs, through access to shared facilities, collaborative research processes and technical expertise (Manufacturing USA, 2024^[183])

In 2025, the U.S. Small Business Administration (SBA) launched the “Manufacturer’s Access to Revolving Credit (MARC) Loan Program”, specifically dedicated to small manufacturers. It targets firms in NAICS manufacturing sectors 31–33, covering food, textiles, chemicals, plastics, metals, machinery, electronics, transport equipment, furniture, and related manufacturing industries. The programme provides flexible working capital to support inventory purchases, new projects, scaling operations, and customer expansion (SBA, 2025^[184]). In 2026, the SBA also announced a “Made in America Loan Guarantee” under its International Trade Loan Program. Covering the same manufacturing sectors (NAICS 31-33) the programme provides a 90% federal loan guarantee to support investments in equipment, facilities,

production capacity, inventory resilience, supply-chain diversification, and strategic acquisitions (SBA, 2026^[185]).

The Workforce Innovation and Opportunity Act (WIOA), enacted in 2014, provides federal funding to states for workforce development and training programs aimed at improving the skills and employability of workers in a rapidly evolving economy. The Act promotes career pathways and sector-based partnerships, enabling employers, including those in advanced manufacturing, to collaborate with workforce boards and educational institutions to design training aligned with emerging skill needs. Manufacturing SMEs can draw on WIOA-supported programmes to upskill workers in areas such as digital technologies, automation and semiconductor production, helping them adapt to evolving technological demands and remain competitive in high-tech manufacturing environments (U.S. Department of Labour, 2025^[186]).

Table 3.6. Summary of analysed policies in the United States

Investment Plan Name	Specific Initiative (if applicable)	Managing Entity	Scope of Implementation	Policy Instrument	Target Group	Budget	Addressed Megatrend
CHIPS Act (2022-2024)	Semiconductor manufacturing	Department of Commerce	National	Incentives for Manufacturing	SMEs, Large firms in semiconductor	USD 39 billion	Digital, Value Chains
	Legacy chip production	Department of Commerce	National	R&D funding	SMEs in automotive and machinery	USD 2 billion	Digital, Value Chains
	Regional innovation hubs	Department of Commerce	Regional	Networking, R&D funding	SMEs, Research Institutions	USD 10 billion	Digital, Value Chains
	R&D and workforce training	National Semiconductor Technology Center	National	Workforce Development, R&D support	SMEs in semiconductor industry	USD 13 billion	Digital, Value Chains
	25% advanced manufacturing investment credit	Department of the Treasury	National	Tax credit	SMEs in semiconductor manufacturing	-	Digital, Value Chains
Inflation Reduction Act (IRA)*	Clean commercial vehicle incentives	Department of Energy	National	Tax credits	Automotive SMEs (clean vehicle parts)	Unspecified	Low-carbon transition, Value Chains
	U.S.-sourced materials for EV production	Department of Energy	National	Tax incentives	Automotive SMEs (electric motors, batteries)	Unspecified	Low-carbon transition, Value Chains
	USD 5/sq ft tax credits for energy efficiency	Department of Energy	National	Tax credits	Electronics SMEs	Unspecified	Low-carbon transition, Value Chains
	Machinery for clean energy systems	Department of Energy	National	Tax incentives	Machinery SMEs	Unspecified	Low-carbon transition, Value Chains
	Clean Energy and Sustainability Accelerator	Environmental Protection Agency (EPA)	National, Regional	Grants, Financing	SMEs in clean energy infrastructure	Unspecified	Low-carbon transition, Value Chains
Bipartisan Infrastructure Law (changes since 2025 apply)	USD 7.5 billion for EV charger infrastructure	Department of Transportation (DOT)	National	Public Infrastructure Investments	SMEs in EV charging, installation	USD 7.5 billion	Low-carbon transition, Digital, Value Chains
	USD 5 billion for electric school buses	Environmental Protection Agency (EPA)	National	Public Infrastructure Investments	SMEs manufacturing electric bus components	USD 5 billion	Low-carbon transition, Value Chains
	USD 65 billion for	Federal	National,	Public	Electronics	USD 65	Digital, Value

	broadband expansion	Communications Commission (FCC)	Regional	Infrastructure Investments	SMEs (network equipment)	billion	Chains
	Energy-efficient upgrades (Weatherization)	Department of Energy	National, Regional	Grants	SMEs in energy-efficient machinery	USD 3.5 billion	Low-carbon transition, Value Chains
	USD 110 billion for infrastructure upgrades	Department of Transportation (DOT)	National	Public Infrastructure Investments	Machinery SMEs	USD 110 billion	Low-carbon transition, Digital, Value Chains

Source: OECD analysis based on desk research.

*The 2025 One Big Beautiful Bill Act (OBBBA) significantly curtailed the Inflation Reduction Act by accelerating the phaseout of many clean-energy tax credits and imposing new foreign-entity restrictions that limit eligibility for remaining incentives.

Note: This table provides an example of the policies researched by the OECD for this project and does not offer a comprehensive overview of the country's policies in the manufacturing sector.

Conclusion

Recent U.S. legislation has introduced a range of measures relevant to manufacturing SMEs, spanning innovation, energy, infrastructure and industrial development.

These measures combine tax incentives, R&D funding, grants and large-scale public infrastructure investments to strengthen competitiveness in sectors such as semiconductors, energy and transportation. Tax credits have been applied in areas including energy efficiency, electric vehicle production and advanced manufacturing, while grants and infrastructure projects have supported investment and activity across related value chains. Workforce development and collaborative initiatives have also sought to address skills needs and facilitate SME participation in evolving industrial ecosystems.

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Notes

¹ French Tech refers to the French government-backed initiative and broader ecosystem supporting startups across sectors. Coordinated by the Mission French Tech and supported by Bpifrance and other public actors, it aims to accelerate the growth of innovative startups through funding, international promotion, and policy support.

² Mid-sized companies or “Entreprises de Taille Intermédiaire” (ETI) in French are defined as having 250 to 4 999 employees and either a turnover not exceeding EUR 1.5 billion or a balance sheet total not exceeding EUR 2 billion.

³ As of January 2025, the bill has been adopted by the Senate and submitted to the National Assembly for discussion.

⁴ Can take multiple forms: Grant/Interest rate subsidy; Loan/Repayable advances/Reimbursable grant; Guarantee; Tax advantage or tax exemption; Risk finance; Other. See: (EU Commission, 2021^[187])

⁵ Reuters (2024), *Volkswagen considers historic German plant closures in cost drive*, 3 September 2024

⁶ Survey of managing directors from VDMA specialist associations and organized companies in the specialist associations for printing and paper machines, plastic and rubber machines, waste and recycling technology, as well as food and packaging machines. Source: VDMA in (McKinsey & VDMA, 2022^[73]).

⁷ 43 companies. Source: VDMA

⁸ All EU, national and regional programmes are gathered and accessible through the online funding data platform (Foerderdatenbank):
<https://www.foerderdatenbank.de/FDB/DE/Foerderprogramme/foerderprogramme.html>

⁹ IPCEI: Important Project of Common European Interest

¹⁰ Currently the following initiatives are involved in the IM-X Council: Alliance Industrie du Futur (France), CESMII The Smart Manufacturing Institute (USA), Confindustria (Italy), Korea Smart Manufacturing Office Kosmo (Korea), Offensive de Transformation Numérique (Canada), Plattform Industrie 4.0 (Germany), Plattform Industrie 4.0 (Austria), RRI Robot Revolution & Industrial IoT Initiative (Japan), Smart Industry Programme (the Netherlands).

¹¹ These areas are: Bioeconomy; biomedicine; electronics, autonomous driving and high-performance computing; energy efficiency, climate protection and adaptation; medical technology; information and communication technologies; interactive technologies for health and quality of life; materials research; photonics and quantum technologies; resource and circular economy; and the future of value creation.

¹² Following the submission of project outline on one of the two deadline dates as well as the application

¹³ For projects of less than EUR 100 000 of equity contribution.

¹⁴ Partners in collaborative projects are composed on average by 60% SMEs and 40% research institutions. The amount of funding per project is variable, dependent on demand, number of projects and overall budget. Funding for the October application window (for projects not exclusively focused on technical innovation) receives co-financing from the European Social Fund Plus Programme “Future of Work”. The project length, once the support has started, usually goes beyond 24 months.

¹⁵ Around of 45% of SMEs with accepted projects under the ZIM reported “SME-innovative” as alternative funding initiative that could have been considered for the R&D project.

¹⁶ The manufacturing sector’s added value in 2022 was JPY 107.6 trillion, and it hired 10.44 million employees out of all 67.23 employees in 2022.

¹⁷ In 2022, nominal labour productivity in the manufacturing sector stood at JPY 10.31 million against JPY 8.27 million on average across all sectors.

¹⁸ Between 2012 and 2022, average nominal labour productivity per capita across all sectors went from JPY 7.92 million in 2012 to JPY 8.27 million in 2022. In the manufacturing sector, it grew from JPY 9.53 million in 2012 and JPY 10.31 million in 2022.

¹⁹ CO₂ emissions of the manufacturing sector / those of all sectors = 247,771 kt CO₂ / 1,064,001 kt CO₂ = 23.3%

²⁰ CO₂ emissions of the machine sector / those of all sectors = 8,981 kt CO₂ / 1,064,001 kt CO₂ = 0.8%

²¹ According to the Japan Institute for Labour Policy and Training, the effective job offer rate, meaning job offer divided by applicants, was 1.31 in 2023. Therefore, there were only 76.3% (=1/1.31) of applicants for jobs.

²² “Japan’s automotive industry is a key industry with world-class comprehensive technological capabilities that supplies vehicles to countries around the world, and it is necessary to take comprehensive measures by paying attention to the goals, regulations, support, and other measures related to electrification in other countries and the status of the electric vehicle market as a result of these measures. Since many of the related industries are dominated by SMEs, we should aim to create an industrial structure that can positively work toward the realization of Carbon Neutrality by responding to electrification, challenging new fields, changing business categories, diversifying, and fostering co-operation and mergers among companies.” (Cabinet Secretariat, METI, Cabinet Office, etc., 2023^[94])

²³ METI argues that to maintain and enhance the competitiveness of Japan’s manufacturing industry, strengthening dynamic capabilities is essential. Dynamic capabilities refer to a company’s ability to

transform itself in response to rapidly changing environments. This includes three key abilities: sensing threats and crises, seizing opportunities by reorganizing assets and knowledge to gain competitiveness, and transforming the organization to sustain long-term competitiveness. Digital technologies amplify all these abilities, especially through data collection and analysis.

²⁴ Toward the goal of achieving carbon neutrality by 2050, METI has established a Green Innovation Fund at the level of 2 trillion yen under the FY2020 Tertiary Supplementary Budget and decided to assign the New Energy and Industrial Technology Development Organization (NEDO) to its operation. In this fund, the government is providing continuous support to companies and other organizations which are committed to taking on the challenge of ambitious targets for 2030 shared by the public and private sectors, from R&D through to demonstration to social implementation over the next 10 years. These target areas where policy effects are significant, and long-term continuous support is required to realize public implementation, from among the priority fields for which implementation plans have been formulated within the Green Growth Strategy, which is a set of industrial policies to create a “virtuous cycle of the economy and the environment.”

²⁵ METI, in collaboration with other ministries and agencies, has been developing and implementing mechanisms for sharing data processing systems across multiple stakeholders. These initiatives, focused on creating interoperable data infrastructures, have been collectively named the Ouranos Ecosystem (METI, 2023^[191]).

²⁶ “Investments are being made at a different level than has been the case up to the present. Micron, Sony, Kioxia, Tokyo Electron, and others have already launched investment plans. The government has been proactive in providing support in recent years, recognising that the infrastructure for a digital society has been put in place and that semiconductors are also strategic commodities from the perspective of security. There are concerns that the industry may become overheated, but it is a high-risk industry, in which fierce competition is endured in order to realise considerable profit.” (Kuroda, 2023^[192]).

²⁷ In July 2024, the U.S. Economic Development Administration (EDA) awarded USD 504 million in Implementation Grants to 12 of the 31 designated Tech Hubs. The remaining 19 Tech Hubs received USD 500,000 Consortium Accelerator Awards to refine their strategies and mobilise additional investment. EDA also provided USD 500,000 each to 18 Strategy Development Grantees to strengthen regional planning and coordination. In September 2025, EDA opened a new funding call for the 19 designated Hubs that had not yet received Implementation awards, enabling them to compete for support for new Implementation projects ([Regional Technology and Innovation Hubs \(Tech Hubs\) | U.S. Economic Development Administration](#)).

Fit-for-Future Manufacturing SMEs

Effective Policies for Transformation

Manufacturing is a cornerstone of global economic value creation, both through its direct contributions to output and employment and through its role in driving technological diffusion and productivity spillovers across sectors. Small and medium-sized enterprises (SMEs) play a key role in industrial ecosystems, generating a substantial share of manufacturing value added and employment across OECD economies. Yet the sector is undergoing rapid transformation. Digitalisation, rising sustainability requirements, and growing supply chain vulnerabilities are reshaping the competitive landscape at an unprecedented pace, presenting SMEs with both new opportunities and significant adjustment challenges.

This report examines these dynamics in three key manufacturing sectors: automotive, electronics (semiconductor) and machinery, where SMEs play an important role but face distinct transformation pathways. It highlights emerging policy approaches to better integrate SMEs into new industrial strategies, including ecosystem-based policy approaches that strengthen collaboration across local and global supply chains, place-based initiatives that support skills development and technology diffusion, and simplified access to industrial programmes to ensure SMEs can participate fully in innovation and transition efforts.



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