pwc

GMIS | Global Manufacturing & Industrialisation Summit

In this report

The Future of Manufacturing - Germany

Foreword

Recovery across all regions has stabilised the global economic outlook for the next five years, with both developing and developed economies contributing to the global GDP growth rate. Amidst this, Germany remains a key contributor to both the global and Eurozone economic performance with its economy expecting to benefit from this global recovery – being an open, export-oriented market. However, the possibility of increasing trade barriers and the digital transformation are potentially key challenges to Germany's mid to long-term growth prospects and must be managed.

Overall, global manufacturing output grew steadily over 2010–16, with Germany being the fourth largest global contributor and the largest within Europe. Germany is globally renowned for its superior manufacturing capabilities and high quality products, which are the result of extensive investments in education and research and development (R&D), not to mention its focus on driving excellence in manufacturing rather than competing on cost. This focus drives Germany's advanced positioning in sectors such as automotive, where German OEMs produce world class vehicles differentiating themselves based on quality, innovation and high performance. Even for niche products, the majority of the German companies including Mittelstand (midcap companies) manage to command a leadership position in the respective product categories they are present in.

"Germany continues to be a global manufacturing leader, with its intent to continue investing in quality and excellence. The emerging Industry 4.0 opportunities promise to enhance the competitiveness of industries and companies, as PwC's 2016 and 2018 global reports also highlight. Given the disruptive nature of these emerging technologies along with growing global competition, German industrial leaders and Mittelstand companies will need to rapidly assess and adopt the relevant technologies and techniques. More broadly, Germany now needs to ensure that the broader ecosystem – government, education and training providers, entrepreneurs, investors, etc – can actively enable the innovation and digitisation agendas and address any gaps."

Anil Khurana
GMIS Organizing Committee
PwC Partner, US & ME, and Advisor

As manufacturing retains its key role in driving Germany's economy and employment, the country cannot remain complacent with its existing achievements. Increasing global competition is likely to impact Germany as other countries increase their manufacturing capabilities through investing in new technologies and skillsets. Germany's focus on the fundamentals of manufacturing has enabled its current strengths but the critical factors for success are changing rapidly.

In this report, we have outlined two key themes for consideration, in order to further enhance Germany's global position in the manufacturing sector:

A. Enabling transformative innovation:

Enhance its manufacturing sector by further enabling disruptive innovation to create new market opportunities

B. Advancing the agenda for digitisation:

Leverage its pioneer status in Industry 4.0 to attain comprehensive industry-wide digitisation across large, medium and small-scale manufacturers

Finally, to successfully retain and strengthen its leadership status in global manufacturing, Germany needs to build a strong ecosystem comprising of the government, manufacturing and technology companies- large and small, industry associations, financial institutions, educational institutions, global suppliers and customers to spur innovation efforts. Additionally, the country needs to continue to strengthen its fundamentals comprising of very capable Mittelstand and a highly trained labour force, while enhancing investments in digital infrastructure to successfully advance the Industry 4.0 agenda over the next few years.

"Germany's manufacturing ecosystem, reputation for quality, and competitive advantage has been built on efficient and effective processes, significant R&D investment, a highly-skilled workforce, and a strong educational and vocational training system. But in times of rapid, sweeping change and disruptive innovation, Germany's prospects of retaining that advantage may now depend on whether it can reshape this ecosystem."

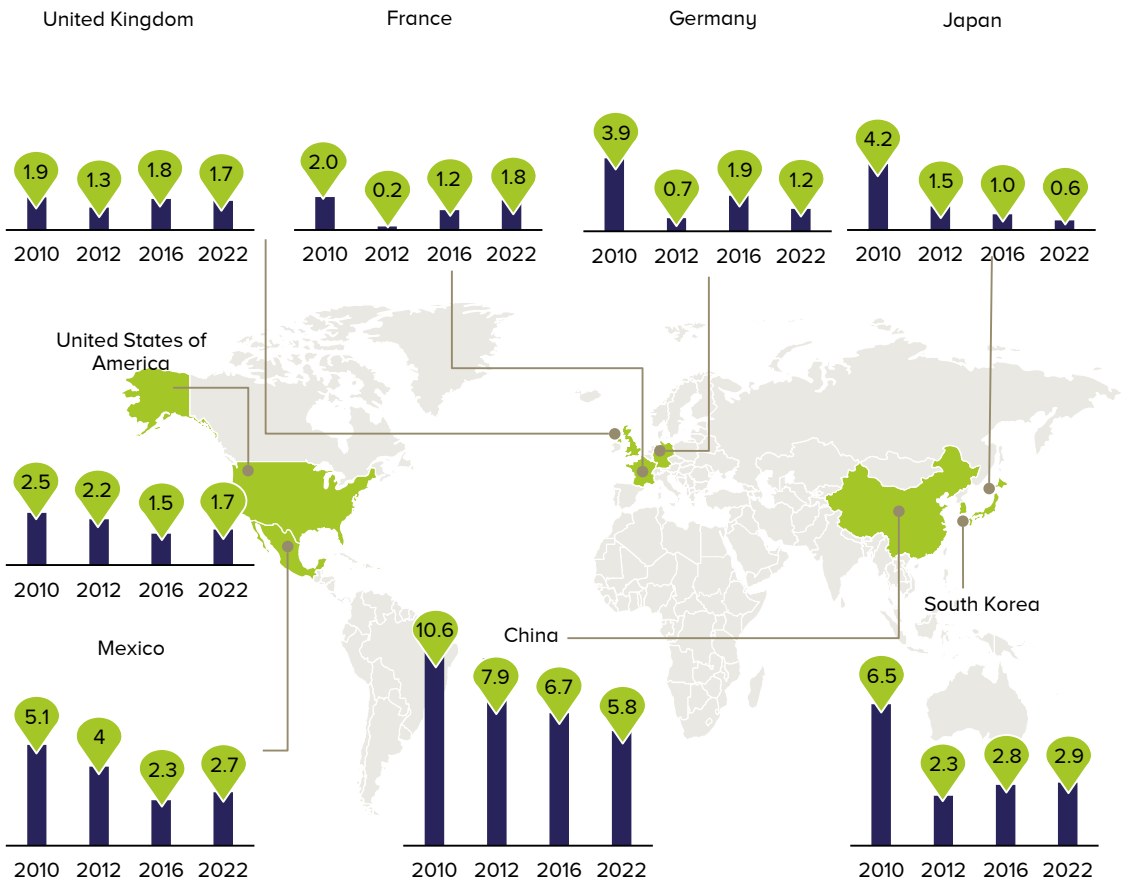
Badr Al-Olama
Head of GMIS Organising Committee,

A macroeconomic snapshot

Global GDP growth reached 3.7% in 2017[1], with improving economic conditions in most regions. Going forward, American tax policy, in particular, is expected to drive short term economic growth for the United States and its major economic trading partners, whilst Europe continues its steady recovery, post the region's sovereign debt crisis.

In 2018, Germany's GDP is expected to grow by 2.0%[2] spurred by the positive developments in global and regional economic conditions as well as recovery in international trade volumes. Overall, top-line growth rates remain higher for the world than Germany due to high growth rates in emerging markets and developing economies (4.9% in 2018)[1], particularly in Asia and parts of Africa. Nevertheless, the German economy has strong fundamentals with positive growth prospects but low inflation and lack of wage growth remain persistent concerns.

Real GDP growth, 2010-22 (%)

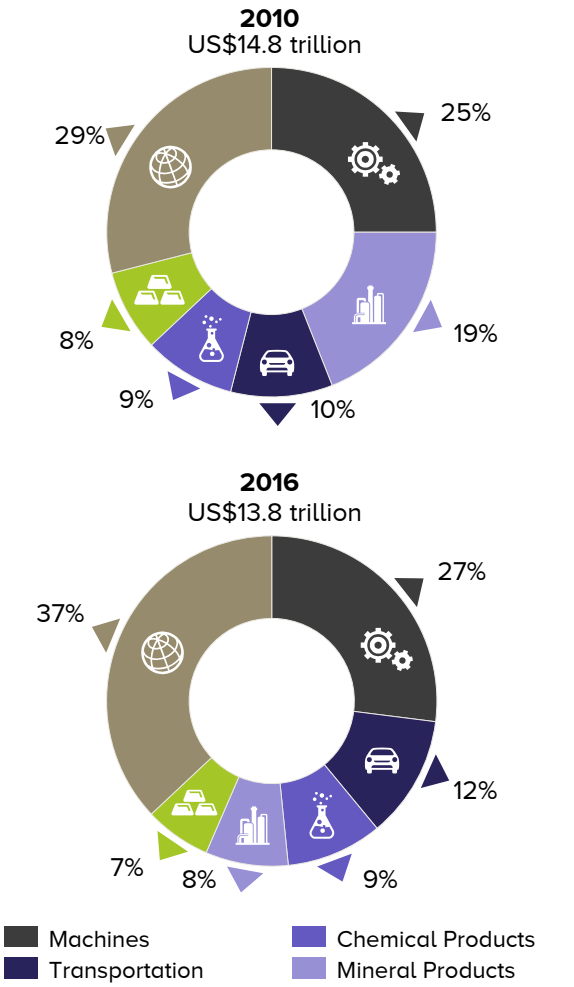


Source: IMF

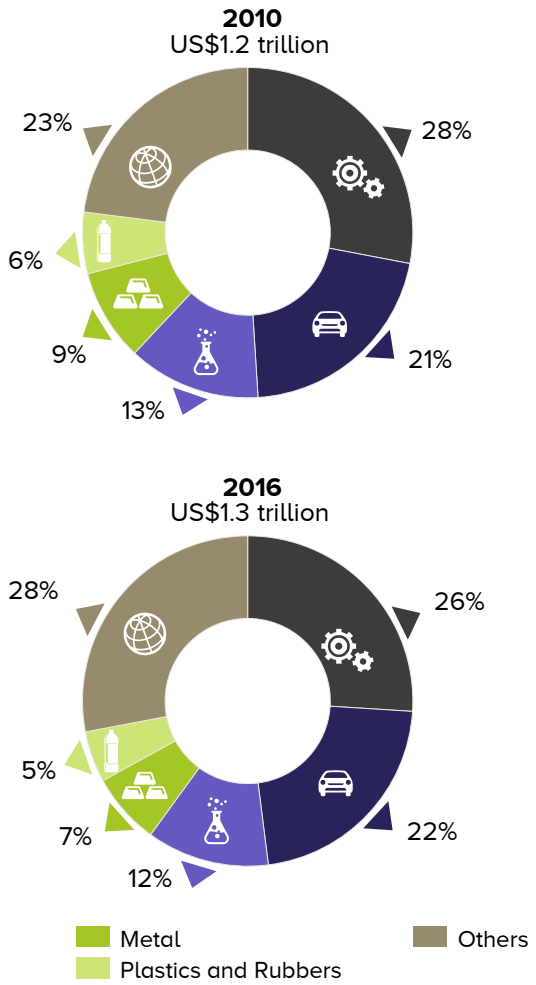
Eurozone economic outperformer

- The Eurozone experienced a tepid recovery from the 2012 – 13 sovereign debt crisis after facing contractions of -0.3%[3] during the two years
- Germany's growth remained stable averaging 2.0% between 2010-16[3], outperforming other Eurozone countries
- Prudent economic management, a strong social safety net and investments in education by the government have helped to maintain positive growth prospects
- However, Germany's GDP growth is expected to slow by 2022. Global protectionism is a cause for concern in the short term with the greatest impact expected in the high-end manufactured goods and capital products sector
- Demographic challenges remain the major concern for mid-to-long term growth prospects as the labour force is expected to contract by 1.9 million in the period 2016 to 2025[4]

Key global goods exports, 2010-16 (%)



Key goods exports from Germany, 2010-16 (%)



Note: Others includes instruments, foodstuffs, textiles etc.
Source: UN Comtrade

Top Exporting Countries (2016)

1. China	US$2.1 trillion
2. USA	US$1.5 trillion
3. Germany	US$1.3 trillion
4. Japan	US$0.6 trillion
5. Netherlands	US$0.6 trillion

Source: UN Comtrade

Top 5 Export Partners (2016)

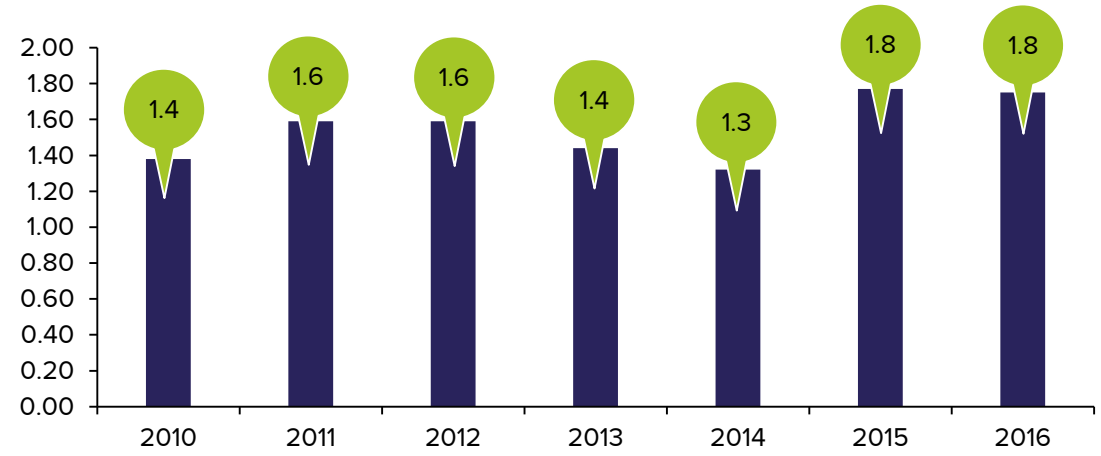
1. USA	9.0%
2. France	8.4%
3. UK	7.1%
4. Netherlands	6.6%
5. China	6.4%

Source: UN Comtrade

Export oriented economy

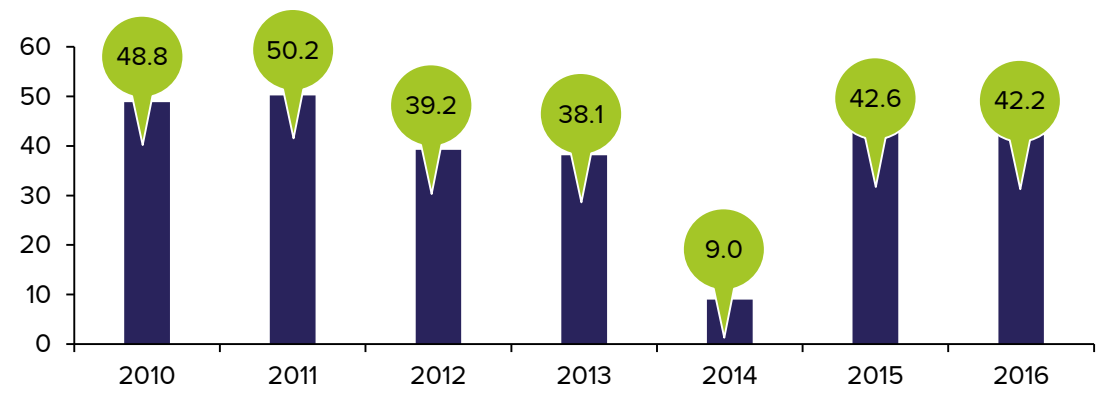
- While global exports of goods have declined between 2010-16, there are positive signs towards a recovery going forward, with an expected global growth of 3.2% over 2017-18[5] and growth in Europe of 2.5% over 2017 – 18[5]
- During this period, goods exports from Germany grew to US$1.3 trillion by 2016 making it one of the top five exporting countries globally. As an open economy that is dependent on exports for growth, Germany will benefit from the projected expansion in world trade over 2017-18.
- Exports of goods and services represented 46% of Germany's GDP[3] in 2016, with manufactured goods, particularly from high quality, high value-added sectors like Machinery and Transportation representing the vast majority

Total Global FDI Flow 2010-16 (US$ trillion)



Source: UNCTAD

Total FDI inflow into Germany, 2010-16 (US$ billion)



Source: BMI

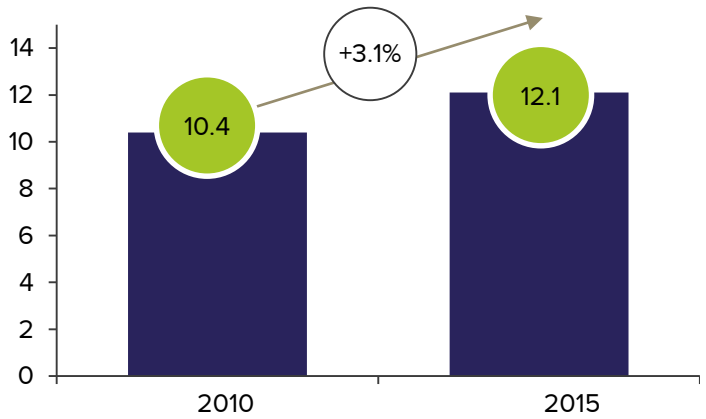
Attractive investment destination

- Global investments rose by 5% in 2017 reaching US$1.8 trillion and is expected to reach US$1.85 trillion in 2018[6]. However, global FDI flows have still not recovered to their pre-recession peak in 2007
- The digital economy is a key area where cross-border investments have increased and is becoming a key enabler of global trade and investment
- 60% of FDI into Germany originates from within the EU[7]. However, Germany has favourable investment policies for all investor countries with no distinctions made between domestic and foreign investments, and has few restrictions on foreign transactions
- China is a growing source of FDI for Germany, and has become the top destination for Chinese greenfield investment. In the manufacturing sector though, investment is more likely to be M&A; 51 of the 99 Chinese M&A transactions in Germany between 2014 and October 2016 were to align with the "Made in China 2025" industrial strategy[8]
- Robust project investments were witnessed in the technology sector (19% of all investment projects), financial services (15%) and manufacturing (45%)[7]

The evolution of German manufacturing

Global manufacturing value add grew at a CAGR of 3.1% between 2010 – 15 to reach US$12.1 trillion by 2015. Of this, Germany accounted for almost 6% and was ranked the fourth largest globally. In spite of intense global competition from countries like China, Germany has managed to retain its core manufacturing advantage by competing based on quality and not just cost, but also on making the necessary investments to retain its role as a differentiated manufacturing destination globally.

Figure 1: The manufacturing sector globally continues to grow steadily
Manufacturing Value Added, 2010-15 (US$ trillion)



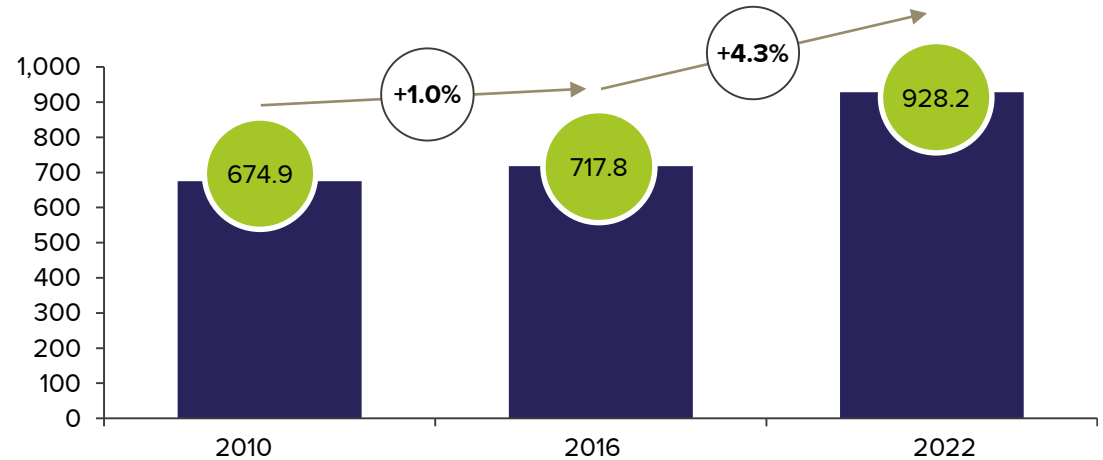
Top 5 Manufacturing Countries (2015)

1. China	US$3.25 trillion
2. USA	US$2.14 trillion
3. Japan	US$892.5 billion
4. Germany	US$700.9 billion
5. South Korea	US$374.5 billion

Note: Most recent available data on manufacturing value added for world is 2015
Source: World Bank

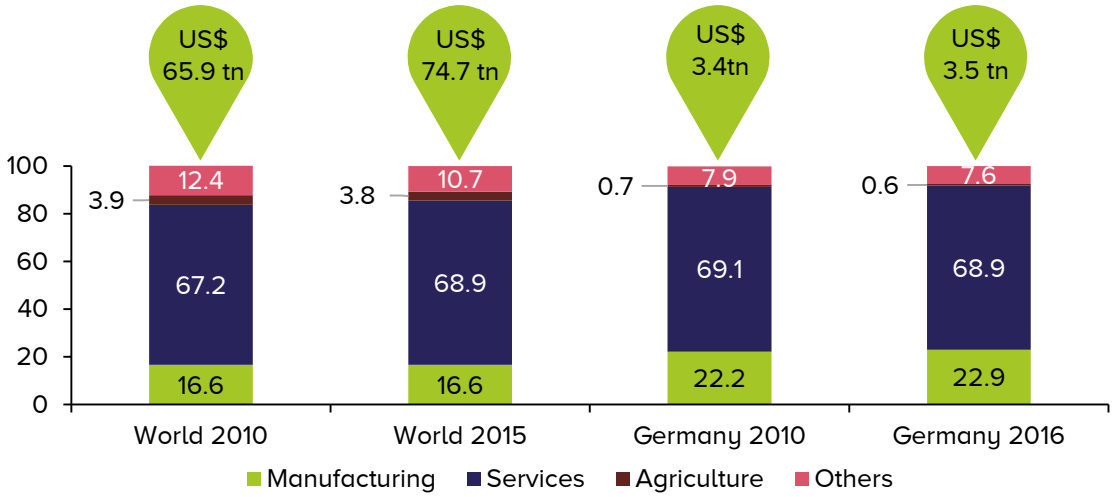
In 2016, Germany's manufacturing value add stood at US$718 billion, representing 23% of the total GDP, with further growth expected at a CAGR of 4.3% between 2016 - 22. Germany's model for manufacturing has relied on a combination of world-class companies in a broad range of manufacturing sub-sectors underpinned by a network of Mittelstand, and this has been critical for success.

Figure 2: Germany's manufacturing output has been an engine of growth for the country
Manufacturing Value Added, 2010-22 (US$ billion)



Source: BMI

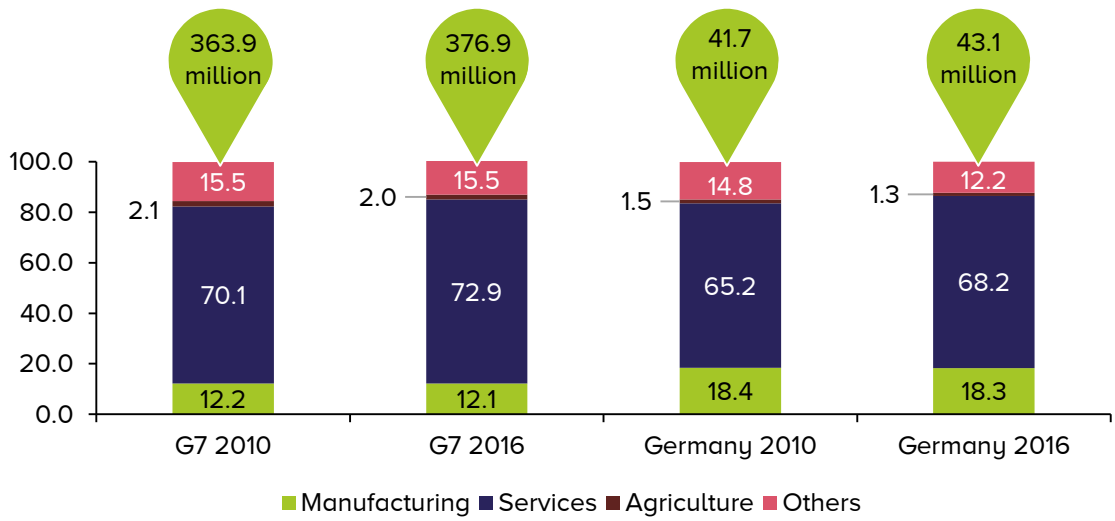
Figure 3: Manufacturing remains a significant contributor to global and German GDP
Contribution of Manufacturing to GDP (%)



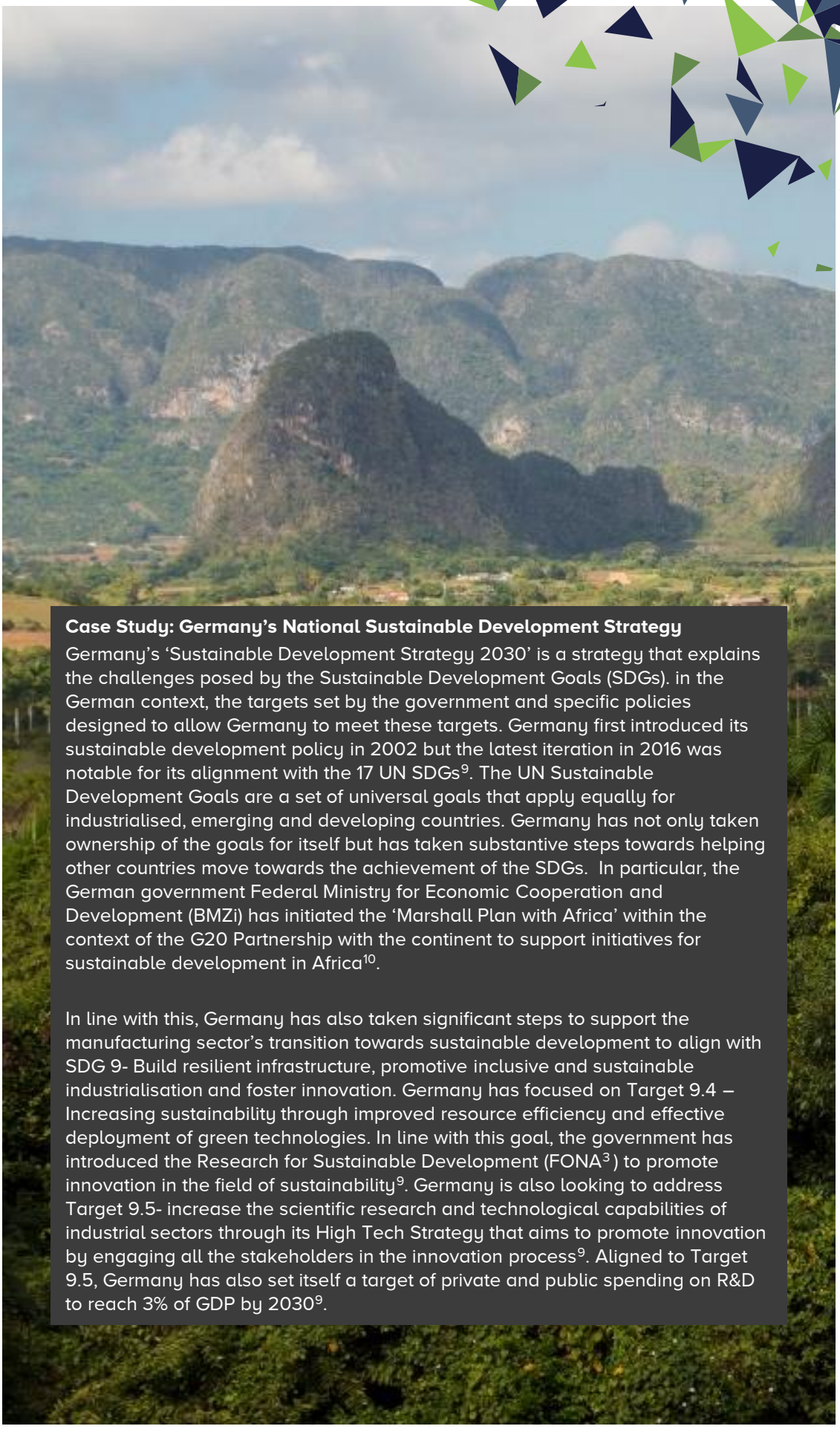
Note: Other refers to other segments in the industrial sector such as mining and construction
Most recent available data on contribution to GDP for world is 2015
Sources: World Bank, BMI

Manufacturing's share of jobs in the highly developed G7 countries has declined since 2010 and the services sector remains the fastest growing and the largest source of employment. In Germany, the sector employed 17% of the total labour force in 2017, with an employment of around 7.5 million[4]. This is expected to increase to 7.7 million by 2022[4], brought about by the rising exports to emerging markets and increasing global demand. However, the overall proportion of manufacturing employment has declined since the 2008 financial crisis when 18.3% of the labour force[4] was then engaged in manufacturing. This decline can be attributed to the structural transformation of the sector due to the growing importance of automation in manufacturing as well as rising employment in the services sector globally.

Figure 4: German employment in manufacturing is robust for a developed economy
Contribution of Manufacturing to Labour Force(%)



Note: Other refers to other employment in the industrial sector such as mining and construction and unemployed persons
Sources: OECD



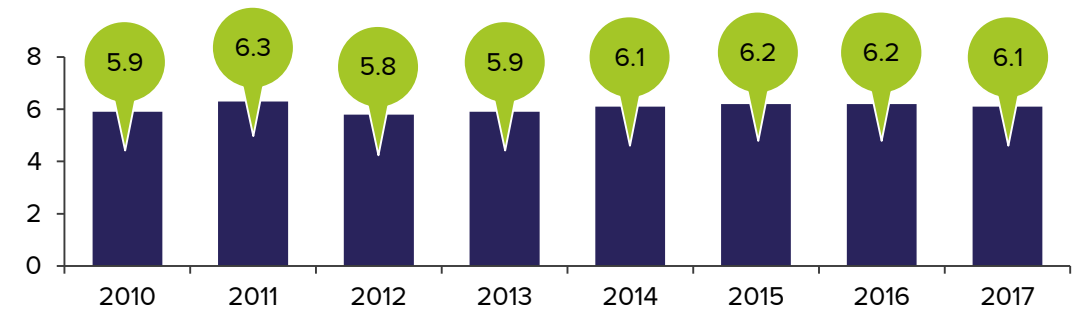
Case Study: Germany's National Sustainable Development Strategy

Germany's 'Sustainable Development Strategy 2030' is a strategy that explains the challenges posed by the Sustainable Development Goals (SDGs). in the German context, the targets set by the government and specific policies designed to allow Germany to meet these targets. Germany first introduced its sustainable development policy in 2002 but the latest iteration in 2016 was notable for its alignment with the 17 UN SDGs[9]. The UN Sustainable Development Goals are a set of universal goals that apply equally for industrialised, emerging and developing countries. Germany has not only taken ownership of the goals for itself but has taken substantive steps towards helping other countries move towards the achievement of the SDGs. In particular, the German government Federal Ministry for Economic Cooperation and Development (BMZi) has initiated the 'Marshall Plan with Africa' within the context of the G20 Partnership with the continent to support initiatives for sustainable development in Africa[10].

In line with this, Germany has also taken significant steps to support the manufacturing sector's transition towards sustainable development to align with SDG 9- Build resilient infrastructure, promotive inclusive and sustainable industrialisation and foster innovation. Germany has focused on Target 9.4 – Increasing sustainability through improved resource efficiency and effective deployment of green technologies. In line with this goal, the government has introduced the Research for Sustainable Development (FONA[3]) to promote innovation in the field of sustainability[9]. Germany is also looking to address Target 9.5- increase the scientific research and technological capabilities of industrial sectors through its High Tech Strategy that aims to promote innovation by engaging all the stakeholders in the innovation process[9]. Aligned to Target 9.5, Germany has also set itself a target of private and public spending on R&D to reach 3% of GDP by 2030[9].

Automotive

Figure 5: Vehicle production, 2010-17
(million units)

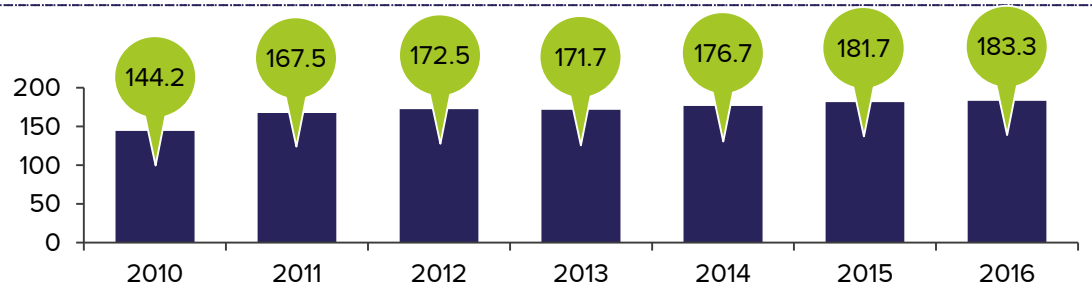


Source: BMI

The German automotive sector has a strong brand associated with quality and reliability, with BMW, Daimler and Volkswagen being the largest companies. Germany is the world's largest exporter of cars (in 2017) with 79% of output directed towards exports[11], forming the vast majority of 'transport' exports. The automotive sector directly employed 851,000 people in 2015[11] with many jobs also indirectly supported by the sector. Overall, the automotive output is dominated by passenger cars (86% of units produced) and light commercial vehicles (11.3% of units produced)[12]. German OEMs account for 75% of the global premium vehicle market[9] which is expected to experience stronger growth (as compared to the overall passenger car market) over the next decade. There are 41 OEM sites in Germany supported by a strong network of suppliers with 85% of auto suppliers being medium sized businesses that contribute to 70% of the sector's gross value-added. The sector is also known for its focus on R&D, with 10% of the industry turnover directed towards innovation and 46% of turnover being created by new products[11].

Machinery and Equipment

Figure 6: Mechanical Engineering Industry Turnover, 2010-16
(US$ billion)

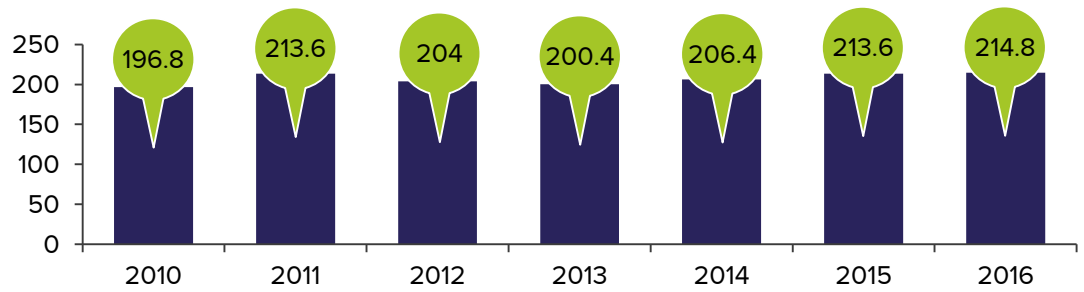


Note; Exchange rate is based on 2016 (€1=US$1.20)
Source: Statista

Machinery and equipment (M&E) form the largest industrial sector (by number of companies) in Germany with 6,400 companies[13], and it was also the top recipient of FDI within the manufacturing sector. While the largest German M&E companies are Siemens and Bosch, 90% of the companies[13] are actually Mittelstand, many of which produce industrial-facing products and are the top ranked suppliers in their niche categories. The top M&E sub-sectors are machine tools, pumps and systems, power transmission, materials handling technology and air handling technology. Global and domestic industrial companies, particularly in the electronics, chemical and automotive sectors are the top customers for these M&E companies. Chinese manufacturing companies are becoming increasingly relevant for Germany, positioning themselves as both customers and investors in this sector. Overall, the sector is highly innovative with 70% of companies investing in innovation, 55% of companies bringing out new or improved products and 31% introducing new or improved processes in 2015[13].

Electrical and Electronics

Figure 7: Electrical and Electronics Industry Turnover, 2010-16
(US$ billion)

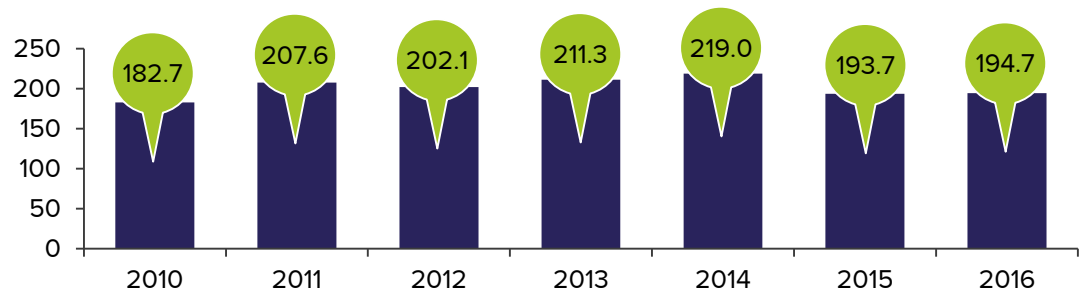


Note; Exchange rate is based on 2016 (€1=US$1.20)
Source: ZVEI

The German electrical and electronics sector accounted for 11% of German industrial production with a turnover of US$235 billion (€191 billion) in 2017[14]. China was the largest customer for German electronics exports in 2017, having surpassed the United States. The industry is highly innovative, spending US$21 billion (€17.2 billion) on R&D in 2017[14], with 70% of the firms regularly introducing new products. The electronics industry mainly serves other industrial sectors with 78% of revenue derived from industrial-facing goods, 12% from intermediate goods and only 10% from consumer goods[14]. The largest demand segments are the automotive sector, industrial electronics and electro-medical technology sectors. Overall, the electrical and electronics industry has an added-value over production ratio of 44%[14] (The value added ratio is the time spent adding value to a product or service, divided by the total time from the receipt of an order to its delivery) which is the highest of all industrial sub-sectors in Germany.

Chemicals

Figure 8: Chemical Exports, 2010-16
(US$ billion)



Source: World Bank

The German chemicals industry employed 415,000 people in 2015[15]. Though the chemicals industry is still a significant sub-sector in German manufacturing and accounted for 12% of total exports in 2016[16], the growth of the industry has been sluggish compared to others. The top output categories are petro-chemicals, fine & specialty chemicals, polymers, anorganic basic chemicals and detergents. The German chemicals industry has faced tough competition from the Chinese chemicals industry, which has grown rapidly since 2005. German companies have increasingly found it harder to produce differentiated products that would be able to command a premium, while also struggling to maintain margins due to high raw materials and energy costs. Therefore, the sector focus is shifting away from basic chemicals and towards specialty chemicals and pharmaceuticals where there is greater room for differentiation. The largest German chemicals companies are BASF, Bayer, Linde and Lanxess.

The Leap Forward

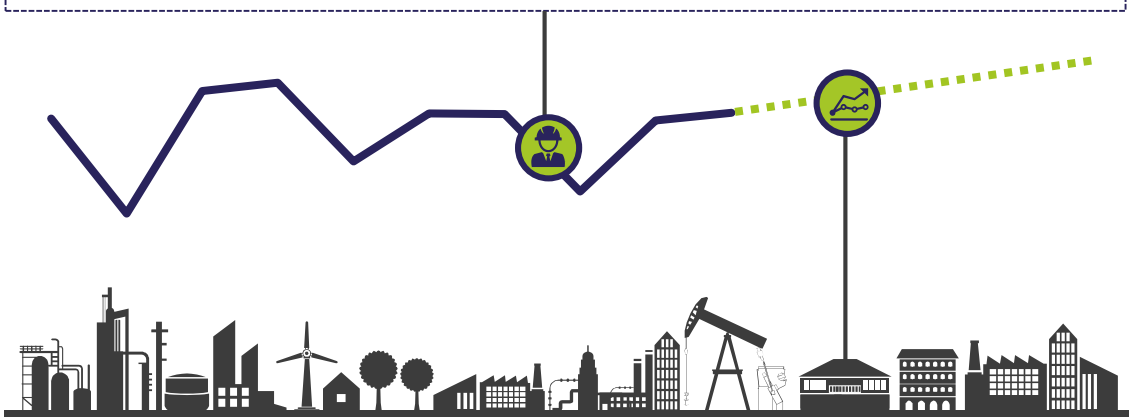
Germany's manufacturing sector is expected to continue being a significant source of revenue and employment for the country. Its success has been based on the fundamentals of a deep understanding of the labour, raw materials and capital equipment required creating high quality output derived from robust processes as well as strong support from the government. Evolving customer expectations are also creating a further impetus for German companies to drive transformative innovation that can anticipate and serve the customers' future needs. Furthermore, while Germany is already a driving force behind Industry 4.0, a successful and comprehensive implementation will still require the collective effort of companies and the government to create a strong ecosystem that can spur innovation and adoption of Industry 4.0 tools.

Figure 9: Germany's manufacturing industry will continue its strong growth
Three key institutions unique to Germany have driven its success in manufacturing

Mittelstand
- Defined as a company with < 500 employees and < €50 million in revenues[17]
- Represents 99.6% of all business in Germany, employs 60% of the labour force and accounts for 68% of Germany's exports[16]
- Developing a niche with a focus on high quality and performance has safeguarded these companies from competition from low-cost markets

Research Institutes (e.g. Fraunhofer-Gesellschaft)
- Bridges the divide between research and market- ready solutions by considering the immediate business applications of their projects
- Identifies areas with a tradition of manufacturing particular goods and provides the R&D support needed to keep these industries at the cutting edge

dual VET
- A vocational training system which includes both vocational school and on-the job training for a period of two to three and a half years
- Provides a steady pipeline of highly qualified talent that has increased productivity
- Standardised training programmes that are kept updated with new technologies



The future of German manufacturing will be shaped by two trends:

1. **Enabling transformative innovation:** Facilitate disruption leveraging Germany's engineering expertise to capitalise on new market opportunities
2. **Advancing the agenda for digitisation**: Capitalise on Germany's Plattform Industrie 4.0 initiative to create fully digitised supply chains and factories

Sources: GTAI, BMI, Fraunhofer-Gesellschaft

A. Enabling transformative innovation

Germany, the largest economy in Europe, is renowned for its superior manufacturing capabilities and quality of goods, as affirmed by the Statista's *Made-in-Country Index 2017* in which consumers ranked "Made-in-Germany" products as the top out of the 52 countries surveyed. Focus on quality rather than competing on cost was the key contributor to Germany's success in manufacturing, with many German companies including up to 1,620 German SMEs[18] ranking either number one or two globally in the product category they are present in.

Germany already has a basic foundation for innovation thanks to the country's comparatively strong education system[19]. The practice of dual VET system in Germany allowed a large proportion of the population to receive advanced qualification through systematic vocational education and training including apprenticeship at public training schools and companies.

This has resulted in a 7.0% youth unemployment rate[20], the lowest within Europe. Besides this, institutions like the Fraunhofer-Gesellschaft, the top applied research organisation in Europe that manages 72 institutes and research units[19] across Germany, ensures a constant stream of talent for the manufacturing, services and public administration sectors.

In addition to education, factors such as high R&D spending and an increasing international focus allowed the creation of new niche products, especially by the Mittelstand where they have gained leadership in new product categories. However, the nature of innovation is still not transformative – involving the development of new or emerging technologies that can create new market demand. This type of 'transformative innovation' is becoming more and more critical in today's world, one that is increasingly characterised by disruptive value propositions and shifting business models, often spurred by the digitisation of these industries.

Case Study: Disruptive innovation in the automotive sector

The automotive industry is an example of a manufacturing subsector where transformative innovation is fundamentally disrupting the business model. The nature of market need is expected to shift as new innovations such as connected cars, specialised high-end long distance vehicles, low-cost/high-volume urban pods, and robo-taxis emerge. The market will move away from the owner/driver/retail model and towards shared fleets and vehicle pooling in many market segments. OEMs will have to contend with a new landscape in terms of competitors (such as Tesla) and customers (such as Uber, Lyft and Google). In the fleet-based segment of the market, OEMs, suppliers and dealers in the US and EU will eventually see their share of profits halved from 85% in 2017[21].

The impact of these changes for the industry will be significant. PwC's Connected Car Report 2016 found that the share of total revenue in the automotive sector that is addressable by today's OEM model is expected to decline to less than 70% by 2030 and the share addressable by new entrants will grow to 45%. In terms of profits, the share addressable by OEMs will decline from 70% in 2015 to less than 50% and the share than can be captured by new entrants will grow to 60%.

Many of these innovations that threaten to fundamentally disrupt the nature of the industry have emerged from Silicon Valley in recent years. To counter this, German automotive OEMs and suppliers have to reposition themselves to be at the forefront of this change driving the global sector.

Driving such innovation requires supporting digital capabilities, and Germany's readiness shows scope for improvement when compared to other developed countries. On the IMD's *World Digital Competitiveness Rankings 2017*, Germany ranked 17th out of 63 countries lagging behind global competitors such as United States, Canada, New Zealand and Australia as well as countries such as the Netherlands and the United Kingdom, closer to home. Its rankings have also been falling as other countries speed up in making the necessary investments in digital infrastructure and skills. The particular areas for improvement would appear to be 'Investment in Telecommunication' (51st), 'Communications Technology' (44th), and 'Digital/Technological Skills or Talent' (43rd). Additionally, the share of fibre connection in total broadband subscriptions for Germany was only 1.8% while the average share in an AAA- rated country is 24.8% and goes as high as 75% in Japan[22]. Per capita spending by the government on ICT is US$1.90 in Germany versus US$3.80 in the United States[23]. The digital competitiveness gap is already impacting the country's industries as the revenue per capita from the internet economy is only US$1,500 in Germany while being double in the United States[21].

Opportunity

Overall, the growing global economy and rising demand from international markets, especially emerging economies, is expected to provide a critical opportunity for German manufacturers to further expand their footprint. However, succeeding in these high potential, but challenging developing markets will require disruptive innovation to deliver a unique customer value proposition in a profitable manner. German manufacturers with a global presence are therefore in a strong position, as they can capitalize on their local presence in different markets and utilize their strong understanding of varying customer needs, to develop and test their innovations in multiple markets concurrently. Through such a process, German manufacturers can then scale their innovations much quicker, as the product can be tailored for the needs of a wide group of customers at minimal effort. An example of such an approach has been provided below.

Case Study: Siemens innovates to create low-cost healthcare technology

For instance, the lack of sophisticated healthcare in emerging markets due to high cost of equipment prompted a joint team of Siemens engineers from Germany, Spain and China to develop the MultiX Select DR, an X-ray machine that costs just one-third of the company's existing products yet offers high quality standards. The MultiX Select DR received great popularity, especially among the small and medium-sized hospitals in emerging markets. However, the machine was also quickly scaled with hospitals in the more developed countries, which adopted it as a backup machine[24].

With disruptive innovations due to set the agenda for manufacturing in many countries, Germany can seize the opportunity to take a collaborative approach towards innovation, leveraging on its current skills and global network. Partnership with other countries thus allows Germany to extend its leading position in the global manufacturing landscape as it facilitates cross-learning that can accelerate the development of innovative and market-ready solutions with high commercialization potential. *Germany has begun to explore this possibility through the Canada – Germany 2 + 2, introduced in January 2018 which will be a joint collaboration between both countries to drive research and innovation for Industry 4.0 enabling technologies[25]. For this programme, an eligible project consortium must consist of at least one small-medium enterprise (SME) and one academic partner from Canada as well as Germany which will allow participants to collaborate on innovation and create mutually beneficial results.*

Challenges

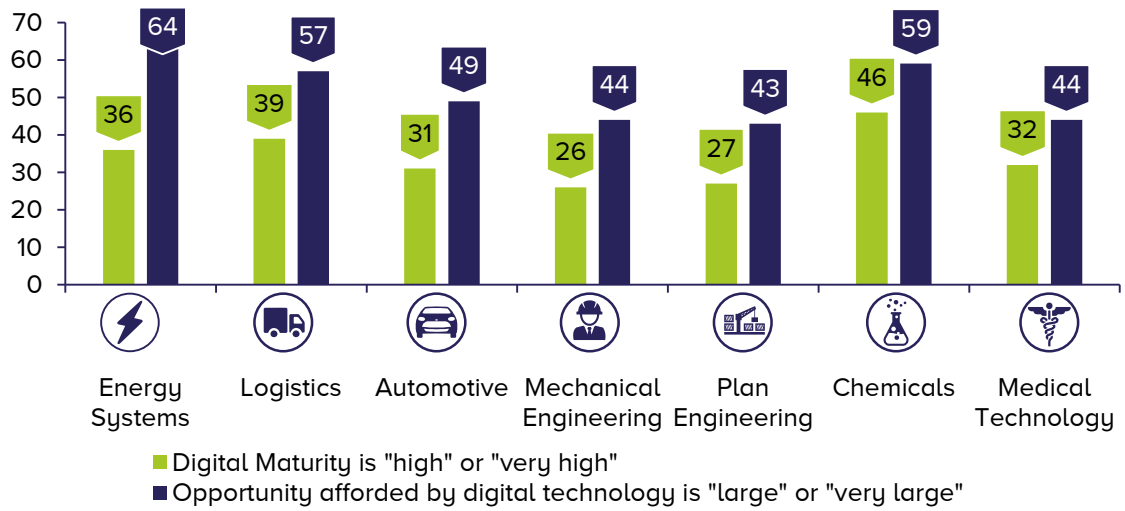
Disruptive innovation requires an ecosystem that is conducive to start-ups and new businesses to develop brand new ideas, test and implement them, and of course, scale to a wider global network. In this regard, Germany's infrastructure in supporting entrepreneurship still has significant room for improvement. Entrepreneurship is crucial to drive disruptive innovation as experimentation and creativity is deeply embedded in the operations of start-ups and young companies. According to a study by the HHL Leipzig Graduate School of Management, 58% of respondents[26] expressed that entrepreneurs faced a critical attitude towards them in Germany while 47% said there was a lack of capital[26]. Institutionally, the long process of starting a business in Germany, which takes 10.5 days as compared to 4 in France and just 1.5 in Canada[26], is also an obstacle.

In the same study by HHL Leipzig Graduate School of Management, 79% of respondents[26] also attributed an 'insufficient culture of failure' in Germany for its waning entrepreneurial dynamic. The success of German manufacturing saw many existing companies having little incentive to change, as engineering-driven innovations have worked well for them and they do not face immediate market pressure to undertake experimentation or fundamentally change their business model. Furthermore, the vocational training under dual VET emphasizes the training of workers to perform a task rather than being encouraged to think out of the box to disrupt an existing product or process.

In addition to entrepreneurship, transformational innovation also requires industry-wide adoption to be successful. The fragmented structure of the German manufacturing landscape, with Mittelstand making up 99% of German companies, thus impedes the rapid permeation of transformative innovation. This is in addition to the increasing struggle faced by Mittelstand for attracting 'digital talent' to create transformative innovation, primarily due to competition from the services sector. Most of the companies are also negatively impacted by their presence in smaller towns and rural areas which makes it difficult to attract potential employees. German companies are failing to capitalize on the full potential of digital transformation especially in the Energy Systems, Logistics and Automotive industries (Refer to Figure 10). As the early mover advantage is significant for digital technology, the relatively slow pace of adoption could be a challenge for the industry moving forward.

Figure 10: The potential of digital transformation in Germany's manufacturing sector is underutilised

Respondents replying affirmatively (%)



Note: Survey of 300 top managers in German Industry
Source: BDI

The Way Forward

Establish an ecosystem for transformative innovation

An innovation ecosystem enables transformative innovation by allowing entrepreneurs and small scale companies be connected with the industry leaders that have the resources and know-how to bring these innovations to the market at scale. Silos between industries as well as between established global players and small & medium enterprises need to be reduced to enable better collaboration for driving disruption. An innovation ecosystem can be successful if it engages the right people, provides opportunities for the sharing of ideas and trains people on how to make best use of the avenues created by the ecosystem. Such an ecosystem provides large companies access to new ideas, technologies and people. An ecosystem can also serve as a shared resource centre for smaller companies and also helps provide credibility – a bank or financial institution is likely to be reassured by the credibility conferred upon start-ups and small businesses that are part of an innovation ecosystem. The ecosystem can similarly also act as a focus point for venture capitalists (VCs) and angel investors who are looking to invest, thereby facilitating access to capital for entrepreneurship.

Pursuing partnerships with start-ups or existing Mittelstand is also a possible solution for industry leaders, as it allows for the mutually beneficial sharing of capital, knowledge and capabilities while also bringing in new ideas and approaches. This will also help the Mittelstand better compete in the German and global manufacturing landscape, as their size makes it a challenge to drive change throughout the value chain. *For instance, GE Digital has an ecosystem of technology partners[27] with varying scale and expertise to allow them to drive innovation and create creative solutions for customers. To achieve this, GE provides partners with access to expertise, different tools, technical benefits (such as demo licenses and training) as well as sales benefits such as joint go-to-market planning.*

Support for transformative development

Overall, there is a need for government initiatives that promote digital enterprise and help shift the culture towards greater acceptance of entrepreneurship. An improvement to the ease of starting a business would be a good start. For instance, the registration processes for a new company can be simplified by having an online one-stop shop portal that can handle federal, state and municipal services, taxes, employment and related matters. Such portals have had pronounced effect in other countries such as Portugal which witnessed a 17% annual increase in firm registration between 2000- 08[28]. Additionally, reducing the minimum capital requirements for businesses (currently at €25,000)[29] would also reduce the barriers to entry for starting a business, particularly for young entrepreneurs. In the OECD countries, 50% of nations have minimum capital requirements that are less than 5% of annual income per capita[30]. In order to catalyse innovation in the digital sector, Germany could also target incentives for these sector or companies that solve specific problems. For instance, Thailand[31] and Singapore[32] provided targeted incentives to companies that are involved in the digital sector and invest in upgrading their own digital capabilities.

In addition to promoting start-ups, further investment in digital and physical infrastructure is also critical for success. According the World Economic Forum's *Global Competitiveness Report 2017-2018*, Germany ranks 10th out of 137 countries for the quality of infrastructure behind countries like the Netherlands, Japan, France and the United States. While this suggests that physical infrastructure is already of relatively high quality in Germany; the score has been trending downwards from 6.4/7 in 2010 to 6.0/7 in 2017, highlighting the need for improvement, especially as other countries are making significant investments to continually upgrade their infrastructure. In addition, high quality infrastructure needs to be available in smaller towns and cities as well - the high concentration of manufacturing businesses in South Germany could serve as the starting point for ensuring this.

Case Study:
Open Innovation Platforms driving innovation in manufacturing

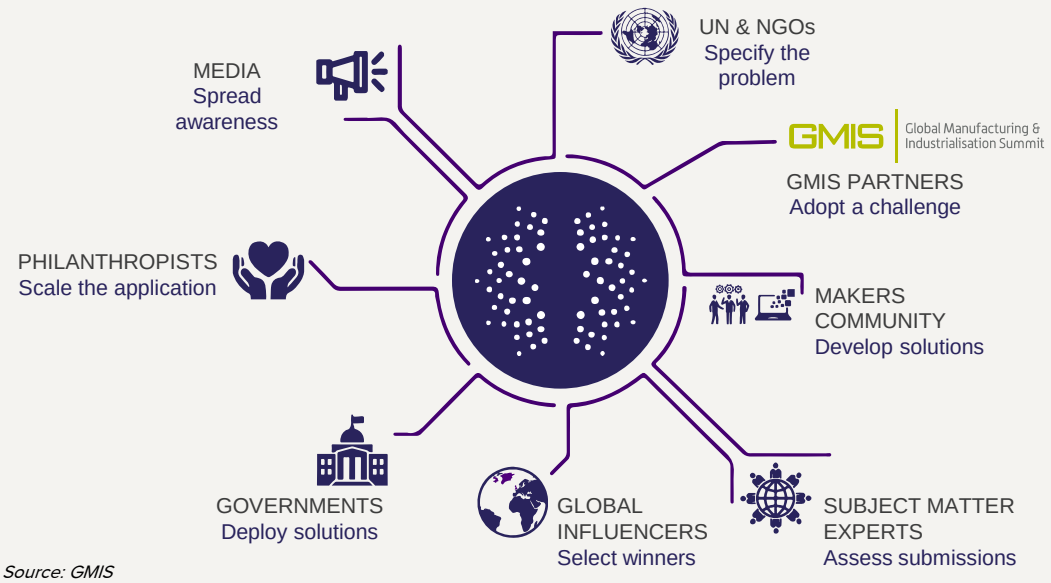
An open innovation platform is a collaboration platform that encourages innovative thinking to solve a particular challenge. The challenges can centre on different phases of the innovation process such as ideation, product testing and research . The scope of these platforms also varies from broad categories such as product development to narrow categories such as optimising batteries.

Initiator	Open Innovation Platform	Solvers
• Group or company that poses challenge • Chooses winning ideas, rewards solvers and operationalises ideas	• Encourages collaboration through gamification, comments, wikis, social media	• Respond to challenges on platform • Collaborates with other solvers to influence idea choices

In this way, the open innovation platform is a way to generate ideas, enable collaboration between different groups of people and create a structured way to generate results. As of 2018, there are different open innovation platforms, each with a different focus and approach. One of the largest open innovation platforms is Quirky[33], with revenue exceeding US$100 million, which focuses on new product development. Initiators post their ideas and designs on the platform and solvers are able to influence projects by sharing their perceptions of the project. The Quirky community guides the process from prototype to marketing through their inputs. Another initiative is the Open Planet Ideas[33], a co-creation platform initiated by Sony and the World Wildlife Foundation (WWF) which focuses on technology for sustainability. Solvers generate technological ideas to solve sustainability challenges posed by WWF and Sony provides the support to realise the vision. The 'realisation' phase of the project has become a kind of inspiration and driving force for the solvers on the platform.

Case Example: MBR Initiative for Global Prosperity

The MBR Initiative for Global Prosperity is an initiative by the UAE government which combines ongoing innovation challenges (MBR Global Maker Challenge) with an annual award (Global Prosperity Award) to solve real world challenges initiated by the GMIS. The MBR Global Maker Challenge is a collaborative competition for startups and entrepreneurs that integrates the innovation needed for manufacturing with the need for solutions to achieve the UN Sustainable Development Goals (SDGs). The initiative leverages on the ability of manufacturing to create new jobs and a path towards inclusive economic development. A structured process will guide the approach of the MBR Global Maker Challenge. Importantly, it engages all the stakeholders (NGOs, governments, global influencers, philanthropists and media) with the ability to scale and realise the value of the solutions generated. The Makers Community will have the opportunity to see the impact of their solutions in the real world and will be incentivised by the Global Prosperity Award.



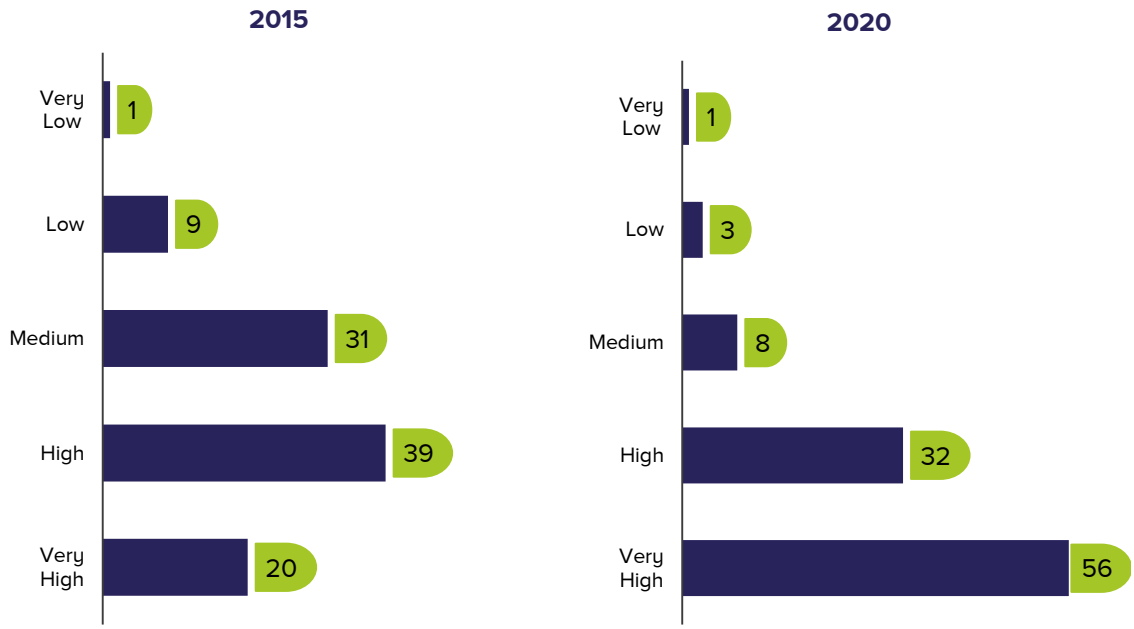
Source: GMIS

B. Advancing the digitisation agenda throughout the manufacturing ecosystem

Germany is at the forefront of Industry 4.0, focusing on pioneering the adoption of digital technologies for the future of manufacturing through the "Plattform Industrie 4.0", part of the High-Tech Strategy 2020. Led by the Federal Minister for Economic Affairs and Energy and Federal Minister for Education and Research, Plattform Industrie 4.0 aims to develop a common understanding of Industry 4.0, providing joint recommendations for stakeholders to create a basis for a consistent and reliable framework. The focus is not solely on the technical components of Industry 4.0 but also on creating the new social infrastructure required to manage the impact on the world of work. This initiative includes multiple stakeholders including industry leaders, industry associations, labour groups and technical experts.

Although Germany was an early adopter of Industry 4.0 it is not necessarily considered the definitive world leader in the field. A 2016 survey by Bitkom research of 559 industrial enterprises found that 25% of companies surveyed thought Germany is the leading country for Industry 4.0, however 28% thought that the United States was the leader in 2016[34]. According to the International Federation of Robotics 2016 report, usage of industrial robots per employee was lower in Germany at 1,131 per 10,000 workers compared to the 2,145 in South Korea. German companies recognize the importance of Industry 4.0 in strengthening the country's competitive advantage (refer to Figure 11), which shows their awareness of the need to adopt and upgrade their own Industry 4.0 capabilities.

Figure 11: Industry 4.0 is of great importance for the competitiveness of Germany
(% of respondents replying on the perceived importance of Industry 4.0 in Germany's position as a business location)



Source: PwC, Industry 4.0 - Opportunities and challenges of the industrial internet

Figure 12: Germany's Plattform Industrie 4.0 is amongst the most advanced platforms globally

	Germany	United States of America	France	Japan	China
Industry 4.0 Initiative	Plattform Industrie 4.0	Industrial Internet Consortium	Industrie du Futur	Industrial Valuechain Initiative Robot Revolution Initiative IoT Acceleration Consortium	Made in China 2025 Internet Plus Manufacturing
Focus	Industry 4.0 for manufacturing	Industrial Internet for 7 sectors including transport, healthcare and manufacturing	Industrial Internet in all sectors including manufacturing, sustainability, transport, mobility and health	Each organisation focuses on the application of its tool across industries	Made in China 2025 is focused on all technological upgrades for manufacturing
Stakeholders	Plattform Industrie 4.0 is initiated by government. Major industrial companies lead the working groups and drive implementation	IIC is a private organisation with domestic and international members and includes manufacturing companies, technology companies and educational institutions	Industrie du Futur is initiated by the government but aims to spur investment by private actors.	Private companies and associations lead the Industrial Valuechain Initiative, Robot Revolution Initiative and IoT Acceleration Consortium	The government leads MiC 2025 and the Internet Plus Manufacturing Plan. Both plans aim to help private and state –supported Chinese companies
Approach	**Plattform Industrie 4.0**: • Work • Security • Norms and Standards • Legal Framework • Research and Innovation	**IIC:** • Business Strategy • Solution Lifecycle • Liaison • Marketing • Security, Technology Testbeds	**Industrie du Futur:** • Technology Development • Assistance for Companies • Employee training • European and international cooperation • Promotional campaign	**Industrial Valuechain Initiative:** • Business Cooperation • Standard Model • Platform • SME Networking • Cross Industries • Educational Materials • IoT Infrastructure • Data Ownership	Specific action areas and working group agendas are yet to be established.
Technologies	• Cyber-Physical Systems • IoT	• Cyber-Physical Systems • IoT	• Transport • IoT • Artificial Intelligence • Big Data • Digital Trust • HPC • Healthcare • Smart cities	• Robotics • IoT • Artificial Intelligence • Sensors	Lacks focus on specific technologies. Has introduced centers for Big Data and Smart Manufacturing Research.
Progress	500 testbeds with Industry 4.0 applications including at universities and research institutions.	The IIC has 26 testbeds as of 2017 and has taken the lead on standardization efforts including working to align Reference Architecture with Germany's Industrie Plattform.	31 companies have been recognized as showcases for the Industrie du Futur in a range of technological areas.	No centralized coordination of pilots currently. Initiatives driven by individual companies.	No pilot projects or testbeds are operational yet.

Sources: Plattform Industrie 4.0, Manufacturing USA, Industrial Internet Consortium, EconomieGouv.fr, Industrial Valuechain Initiative, i-Scoop, Center for Strategic and International Studies, Lehman Brown China

Opportunity

Though Germany has an established reputation in manufacturing, it cannot deny the increasing competition from other countries, particularly from Asia. Large manufacturing capacities in China, cheaper labour costs in Southeast Asia and fast technological innovations from South Korea are just a few examples of potential threats to Germany's leadership in global manufacturing. This situation therefore requires German companies to further amplify their competitive advantage in global manufacturing through greater adoption of Industry 4.0, which focuses on the end-to-end digitisation of all physical assets and integration into digital ecosystems with value chain partners.

A comprehensive adoption of Industry 4.0 is expected to deliver multiple revenue, cost and efficiency gains for companies. Amongst these, a couple of areas that German companies can potentially focus on include delivering greater customer value through personalised products and mass customisation, as well as developing a digital supply chain to be more agile and efficient. By developing the ability to mass customize products, German companies can be better positioned as they gain first-hand understanding of new customer needs and expectations, and are able to deliver customised products within a shorter lead time. Implementation of digital supply chains also allows a stronger connection between OEMs and their suppliers as well as customers, minimizing waste and lead times throughout the entire value chain. Industry 4.0 tools would even enable the design process to be more integrated with the production process, leading to potential savings. For the automotive industry, this can be to be tune of US$100 million per car launch[35].

Overall, through adoption of Industry 4.0, reshoring production back to Germany is also a possibility as manufacturers are able to gain stronger competitive advantage via local innovation as compared to the offshoring production model. Low-cost manufacturing countries are typically struggling with the adoption of automation due to a lack of skilled talent and investment capability, besides the logistical challenges that result in high costs and long lead time to get products into the customer's hands. 75% of German companies[36] cite the efficiency of a local digital factory compared to an offshore factory as a key reason for adopting this model.

Case Study: Adidas launched the Adidas Speedfactory in Ansbach during 2017

Adidas managed to reshore some of their sports shoe production capacity to Germany, with the launch of the 'Speedfactory'. Though the targeted annual production of 500,000 shoes[37] is a small proportion of their global sales, the main aim of the new plant is to shorten the entire supply chain cycle so that customers can get new designs almost immediately. With the entire process from design to production being manned by robots, the new plant is highly flexible and efficient with a lead time of less than a week, between product design and placement in stores (the typical lead time is 18 months[37]).

As more countries and companies move towards Industry 4.0, common regulations, technological standards and reference architecture are required for effective transformation. Germany's Plattform Industrie 4.0 provides the platform for standardization and alignment, thereby giving the country a head start towards establishing itself as the global leader for Industry 4.0.

.

Challenges

A fully realized Industry 4.0 vision will also require creating an ecosystem where Mittelstand and the global value chain can be full members of the digitized supply chain. While large German companies have taken significant steps in beginning to implement Industry 4.0 tools, they will face challenges in finding and developing the right talent that can operate in the new context. Companies will also need to develop new capabilities such as data management that may not have been at the core of their business in the past.

A comprehensive Industry 4.0 transformation requires implementation and adoption throughout the ecosystem, including all suppliers and partners. A 2016 Bitkom Research survey of 364 German companies who were users and players of Industry 4.0 services in their companies found that 75% of companies felt high investment cost was an obstacle they encountered. Similarly lack of specialists (53%) and complexity of the field (50%)[38] were particular challenges. Given that the capital, labour and technology requirements are fairly onerous for smaller companies, the large network of Mittelstand in Germany may not have enough resources and capabilities to successfully transform themselves, and this can potentially restrict the widespread adoption of Industry 4.0 throughout the sector, at the pace demanded by the market. Additionally, global players may face challenges in transitioning international suppliers to Industry 4.0, as they may also be facing hurdles in terms of digital connectivity, investment capital and availability of skilled talent in their respective countries.

In addition, German manufacturing companies need to also cope with the dual challenges of the ageing of their existing workforce and the need for a new pool of talent with relevant Industry 4.0 skills. As the workforce ages, these companies will find their most experienced workers retiring while having to cope with significant change in the job scope and skills required of new employees.

To illustrate this, the share of the population aged 65 and above will be 25% in Germany[39] by 2025 as compared to 17% in the United States[40]. Germany will also face a challenge in changing the mindset and attitude of business leaders, who might not want to disrupt the status quo of how business is done. This next generation of leaders will need to develop new skills around how to manage a digital business model. This is especially critical for Mittelstand which are largely family-owned businesses, where the sense of autonomy and ownership accorded to the owners helps sustain the Mittelstand model.

Industry 4.0 transformation will also bring about an explosion of data that requires effective management to be able to derive meaningful value and cope with the associated risks. The same Bitkom Research survey found that 55% and 51% of German industrial companies[38] cited demands of data protection regulations and data security respectively as key obstacles for usage of Industry 4.0 applications within their company. However, the core competency of manufacturing companies is not in data management, not to mention that the changing standards as well as regulations makes it even more daunting for these companies to fully embrace the possibilities enabled by these Industry 4.0 tools. While Germany has taken proactive steps in terms of standards and legal framework regarding data management, full alignment between national, regional and local standards has not been reached which adds to the challenge. This is further supported by the Bitkom Research where 40% of German industrial companies cite lack of legal framework and 36%[38] mention lack of standards as impeding their usage of Industry 4.0 applications.

The Way Forward

Support the Mittelstand's digitisation journey

With high investment costs cited as a key obstacle for adoption of Industry 4.0 applications in German industrial companies, the government can focus on improving Mittelstand's access to capital, particularly in obtaining loans for technology upgrades. The government could encourage financial institutions to develop specialised solutions for Industry 4.0 financing such as those done by *Siemens Financial Solutions, which provided a leasing solution for Industry 4.0 technology to Friedrich A Kruse jun International Logistics[41], that allowed them to finance the technology via its operating cash flow instead of a large scale investment purchase.* However, the government would need to play an active role in helping the financial institutions establish the types of loans required, as they might not fit into the traditional financing options available. The government may also support banks by giving them tools to conduct proper risk assessment of companies seeking out these loans. Public financing or tax incentives could be another source of capital for certain Industry 4.0 activities that brings about wider societal benefits, for instance, employee training and development.

In addition to the role of government, the industry leaders themselves need to play a central role in the digitisation journey of their suppliers. Consequently, a collaborative approach would be critical to success. For example, when an OEM adopts a new technology, it could also develop a protocol for the on boarding of its suppliers on the new platform as well as provide them support in procurement, standardisation and data management. They could also provide tools to help Mittelstand (as well as global suppliers) manage the change in terms of technologies, processes and people, for instance, by conducting training sessions for their employees and providing supervision. Such close collaborations have been successfully conducted by other businesses. *For example, Ikea supports technology upgrades for its suppliers in China and South East Asia by assisting them with the technology needed to improve their operational and duplicative capabilities. Suppliers are provided help in choosing production technologies, Ikea personnel supervise training, after-sales and maintenance services and suppliers are offered the chance to visit Ikea production facilities to learn production technologies[42].*

Enable widespread use through Plattform Industrie 4.0

Plattform Industrie 4.0 could work to increase the user-friendliness of its standards, addressing the point that 50% of German companies[28] surveyed cited 'Complexity of the field' as an obstacle in adopting Industry 4.0 applications. The focus needs to be on simplifying standards, reference architecture and data security standards, as well as aligning them with international and EU standards. The prominence of Mittelstand in the German manufacturing sector also creates an added importance for the Plattform to ensure that the standards are easy to adopt by these companies, keeping in mind that they are typically constrained in resources. Sponsorships of audits on technology standards for Mittelstand in Industry 4.0 adoption could also encourage widespread adoption as they can help identify gaps/areas of improvement and also act as a feedback mechanism to better adapt standards to the needs of Mittelstand. On the whole, the government's approach to Plattform Industrie 4.0 should be to reassure companies of policy stability going forward.

Ready the German workforce for Industry 4.0

While the German manufacturing labour force is highly trained, the skillset requirements can be redefined to reinforce development of a digital mind-set, and even incorporating business exposure alongside traditional engineering and technical skills. The shrinking workforce in Germany will see higher competition across sectors for attracting the right talent, making it necessary for manufacturing companies to differentiate their value proposition through various mechanisms, such as offering of apprenticeships specific to Industry 4.0 that can train the labour force and entice these employees to stay with the company in the long-run. Re-skilling programmes for the existing labour force are also needed, where success needs to be measured by solution-driven and customer-centric parameters relevant to the needs of Industry 4.0. Given the rapid evolution of Industry 4.0, lifelong learning programmes would also be critical for the labour force to remain relevant in the long-run. With the changing nature of manufacturing jobs, worker flexibility will also be increased given the likelihood of more jobs becoming freelance, which will underline the need for a robust and adaptable social safety net.

Case Study:
Industrial Internet Consortium making the case for the IIoT

The Industrial Internet Consortium (IIC), which is headquartered in Needham, Massachusetts in the United States, was conceived in March 2014 with the stated mission of "deliver(ing) a trustworthy IIoT in which the world's systems and devices are securely connected and controlled to deliver transformational outcomes".The founding members and initial driving force for the initiative came from American technology and manufacturing companies- GE, IBM, AT&T, Cisco and Intel. However, the vision of the IIC is as a global organization with membership from foreign and domestic institutions including small and large companies, industry associations, universities and even government organisations. Seven Industries have been chosen as areas of focus by the IIC: Manufacturing, Healthcare, Energy, Mining, Retail, Smart Cities and Transportation.
The IIC has a steering committee balanced between large and small representatives from industry and includes a representative for academia or a non-profit. The steering committee is responsible for the creation of working groups. There are currently 19 working groups in 7 broad areas: Business Strategy & Solution Lifecycle, Liaison, Marketing, Security, Technology and Testbeds. The IIC also publishes its own Journal of Innovation on a quarterly basis to highlight thought provoking new ideas in the field. The IIC's focus on best practices allows it to be more responsive to changes in technology. Its broad focus on a range of industries may also allow it to drive more innovative practices by reducing the silos between the industries in their use of Industrial Internet tools.

Key Initiatives:

 **Industrial Internet Interoperability Coalition (I^3C)**	 **Industrial Internet Reference Architecture (IIRA)**	 **Industrial Internet Security Framework (IISF)**
The goal of the I^3C is to establish universal interoperability in the realm of IIoT. The complexity of the task required a coordinated approach with inputs from multiple organisations which led to the creation of the I^3C initiative within the IIC. The I^3C established interoperability hotspots that require attention and directs the attention of members towards addressing these issues.	The IIRA is a standards based architecture template and methodology that establishes the basic framework and concepts within which IoT system architects can operate. The IIRA has been updated routinely to reflecting changes in technology and its applications and is currently on v1.8 introduced in January 2017. Importantly, the IIC has collaborated with Plattform Industrie 4.0 to align the IIRA with the Reference Architecture Model for Industrie 4.0 (RAMI4.0) despite RAMI4.0's focus on the manufacturing domain.	The IISF is a document providing guidelines, frameworks and best practices to ensure security in the realm of IIoT systems. The IISF acts as a starting point for system conception and design related to security. As cybersecurity is a major concern for companies embarking on an Industrial Internet transformation, this documents creates a shared understanding of standards to drive trustworthiness.

Industry Example: Condition Monitoring & Maintenance Testbed

Testbeds are a useful tool to test the viability of new technologies, products and applications. Testbeds have been a major area of focus for the IIC. The IIC's role is to provide guidance for testbed proposals and to act as a forum to share the demonstrated benefits of the testbeds. A testbed in the manufacturing space initiated by IBM and National Instruments is the 'Condition Monitoring and Maintenance Testbed' in Austin that uses a predictive maintenance solution to offer continuous online measurements, automated predictions on maintenance and equipment failures. The testbed has helped demonstrate the value of predictive maintenance that will enable companies to increase production and reduce downtime. The testbed will be expanded to new applications based on the results of this testbed.

Source: Industrial Internet Consortium

Conclusion

Germany's leadership in the global manufacturing landscape has been driven by the focus on high quality and innovative products, and this has led to many German companies commanding the top positions in their respective product categories. As a result, Germany has become one of the major goods exporters globally, and improving economic conditions worldwide are expected to drive further demand for German products. Germany has maintained its strength in high quality manufacturing through an efficient and effective process, facilitated by the country's high R&D spending and trained labour force.

However, the rapidly changing manufacturing landscape, with several disruptive innovations, has the potential to erode Germany's competitive advantage in this sector. The need therefore, is to create an environment to facilitate transformative innovation within manufacturing to create new market demand through better anticipation of customer needs. To achieve this, Germany needs to have the right ecosystem to better promote entrepreneurship supported by a robust, and continually upgraded digital infrastructure. Germany also needs to adopt a partnership approach bring together multiple stakeholders to create an ecosystem to drive disruption.

In addition to disruptive innovation, the German manufacturing sector also needs to ensure widespread adoption of Industry 4.0 to differentiate themselves globally, potentially achieving benefits such as a digitally enabled supply chain as well as mass customisation. To realise this goal, it is essential that the Mittelstand's digitisation journey be well supported in terms of access to capital, technology and skillsets.

Overall, the ability for Germany to reinforce and sustain its leadership in global manufacturing will be highly dependent on its ability to drive transformative innovation through an advanced digitisation agenda. Furthermore, the German government, manufacturing companies and other participants (like financing institutions etc.) need to undertake a participative approach including collaboration with other countries as well as international partners, as a collective effort is essential for the speed to success.

"If Germany has to stay a world leader, it will need to encourage its industrial champions to recognize that they are truly in the midst of a major revolution. This will need new research on production systems, re-design of the concept of the factory, shifts in career models, and wider availability of needed skills. Traditional engineering discipline will need to be supplemented with business awareness. Above all, this will also require a shift in mindset – recognize systemic gaps, enable business agility, redesign career paths, be open to emerging business models, and even greater industry collaboration."

Anil Khurana
GMIS Organizing Committee
PwC Partner, US & ME, and Advisor

"As this in-depth analysis shows, Germany has the foundations for innovation in place. The focus, globally, must now turn to transformative innovation – the brand of innovation that creates new market demand, and changes the game. To do this, there needs to be more emphasis on supporting digital capabilities, entrepreneurship, and the industry-wide adoption of new technologies. In all of these areas, there is scope for improvement, illustrating that even the best can always be better. "

Badr Al-Olama
Head of GMIS Organising Committee,

Authors & Contacts

Dr. Anil Khurana
Committee Member, Global Manufacturing & Industrialisation Summit,
Partner, Strategy & Innovation, PwC Middle East and US,
ME lead – Consumer & Industrial Products & Services

T: +971 50 883 6369
E: anil.khurana@pwc.com

Badr Al-Olama
Head of GMIS Organizing Committee

E: info@gmisummit.com

Mohammad Shaban
Director of Strategy
Global Manufacturing & Industrialisation Summit (GMIS)

T: +971 55 900 8363
E: mohammed@gmisummit.com

David Wijeratne
Partner, Growth Markets Centre Leader, PwC

T:+65 6236 5278
E: david.wijeratne@sg.pwc.com

Dr. Reinhard Geissbauer
Head of EMEA Industry 4.0
Global Head of Digital Operations Impact Center

T: +49 170 939 1263
E: reinhard.geissbauer@strategyand.de.pwc.com

Acknowledgements

- Sidharta Sircar, Director, Growth Markets Centre, PwC
- Jan Pasemann, Growth Markets Centre – EMEA, PwC
- Janice Teng, Senior Manager, Growth Markets Centre, PwC
- Aparna Chandrasekar, Growth Markets Centre, PwC
- Anishta Lakhani, PwC Middle East

Notes

1. IMF, World Economic Outlook, 2018
2. BMI, Germany Country Risk Report, Q2 2018
3. World Bank, World Development Indicators 2016
4. BMI Forecast, Germany, 2018
5. WTO, International Trade Statistics, 2018
6. UNCTAD, World Investment Report 2016
7. GTAI, Economic Overview Germany, 2018
8. Bertelsmann Stiftung, Challenge and Opportunity-Chinese Direct Investment in Germany, 2016
9. German Federal Government, German Sustainable Development Strategy, 2016
10. Federal Ministry for Economic Cooperation and Development, A Marshall Plan with Africa
11. GTAI, The Automotive Industry in Germany, Issue 2016/2017
12. ACEA, Statistics, 2018
13. GTAI, The Machinery and Equipment Industry in Germany, Issue 2017/2018
14. ZVEI Die Elektroindustrie, German Electrical & Electronic Industry- Facts and Figures, 2017
15. GTAI, The Chemical Industry in Germany, Issue 2017/2018
16. UN Comtrade, International Trade Statistics Database, 2018
17. BMWi, The German Mittelstand: Facts and figures about German SMEs, 2016
18. ASME, 'How Does Germany Do It?', November 2013
19. OECD Data, Q4 2017
20. Fraunhofer website, Institutes
21. PwC Strategy&, The 2017 Strategy& Digital Auto Report, September 2017
22. S&P Global Ratings, Germany Is Losing the 'AAA' Infrastructure Report, 23 November 2017
23. FT, 'Why Germany needs to accelerate into the digital fast lane', 25 January 2017
24. University of Bamberg Press, Innovation Landscape in Developed and Developing Markets, 2016
25. Natural Sciences and Engineering Research Council of Canada, Joint Canada–Germany 2 +2 call on Advanced Manufacturing–Industry 4.0, January 2018
26. The Local De, 'Germany is losing startups due to lack of spirit:report',1 December 2016
27. GE Digital, Meet Our Ecosystem
28. World Bank Doing Business, Doing Business Reforms, June 2017
29. DLA Piper, Corporate- Minimum capital requirement, May 2017
30. World Bank Doing Business, 'Why are minimum capital requirements a concern for entrepreneurs?', 2014
31. EDB Singapore, Singapore fast-tracking to become Asia's digital capital, 7 June 2017
32. Open Gov Asia, 'Thailand 4.0 Means Opportunity Thailand': Government taking steps to attract investments in targeted industries, 1 June 2017
33. Board of Innovation, How to kickstart your co-creation platform 20 examples
34. Bitkom Research, Leading countries in Industry 4.0 worldwide, 2016
35. HBR, 'German Manufacturing Is Leading a Digital Industrial Revolution', 1 June 2016
36. PwC, Digital Factories 2020 Shaping the future of manufacturing, April 2017
37. Economist, 'Adidas's high-tech factory brings production back to Germany', 14 January 2017
38. Bitkom Research, Industry 4.0- obstacles regarding application in German companies, 2016
39. European Commission, The 2012 Ageing Report, 2012
40. US Census, An Aging Nation: The Older Population in the United States, May 2014
41. Industrial In, 'Germany and the US: A Transatlantic Race to Digital Manufacturing', 21 September 2016
42. Journal of Economic Geography, Upgrading in global value-chains: a case study of technology-learning among IKEA-suppliers in China and Southeast Asia, 28 April 2010

Uniting the world in shaping the future of manufacturing is the goal of the Global Manufacturing & Industrialisation Summit (GMIS). A unique and unprecedented cross-industry forum, we bring together governments, the business world, and civil society to create a roadmap of the development of a sector that accounts for million jobs, 17% of global GDP, and 84% of world trade exports – ensuring its evolution mirrors the way the world is changing and supports progress toward the UN Sustainable Development Goals.

A joint initiative by the United Arab Emirates and the United Nations Industrial Development Organization, GMIS – as a platform for leaders to transform manufacturing, a builder of cross-sectoral partnerships, and a knowledge-base that identifies opportunities for the sector to generate universal benefit – is committed to placing manufacturing at the heart of economic regeneration, policymaking, international collaboration, and contribution to global good. Find out more about the GMIS mission, and how you can be part of it, at www.gmisummit.com

At PwC, our purpose is to build trust in society and solve important problems. We're a network of firms in 157 countries with more than 208,000 people who are committed to delivering quality in assurance, advisory and tax services. Find out more and tell us what matters to you by visiting us at www.pwc.com. Established in the Middle East for 40 years, PwC Middle East has firms in Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Oman, the Palestinian territories, Qatar, Saudi Arabia and the United Arab Emirates, with around 4,000 people. (www.pwc.com/me).