World Economic Forum

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White Paper

Manufacturing Our Future
Cases on the Future of Manufacturing

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Contents

Introduction: Manufacturing Our Future

***Manufacturing is a tool to improve standards of living*.** From better and cheaper products to increased economic opportunities, lower unemployment and a better quality of life, manufacturing can be a tool to support national development goals. The World Economic Forum Global Agenda Council on the Future of Manufacturing collaborated with other Forum Councils to assess the capabilities manufacturing can bring to both developing and developed countries.

Manufacturing is indeed the foundation for building economic prosperity in industrialized nations. Today, technology and innovation drive growth within the sector and spur a constant upgrading of its capabilities. Manufacturing evolves through global economic dynamics, as well as advanced equipment and processing technologies, to produce more diverse and sophisticated products. Thus, it opens the door not only for employment that requires higher skill levels at higher wages, but also for a greater convergence of skills. Understanding the changes in manufacturing will enable economies to establish their own capabilities to innovate and set new development opportunities, including multiplying effects on wages.

The link between a thriving manufacturing sector and economic growth is a direct and significant one, particularly regarding employment and industries that themselves are linked. In fact, manufacturing has the largest multiplier effect of any economic sector.

Source: US Department of Commerce, Bureau of Economic Analysis, Industry Input-Output Tables (2013).
http://www.bea.gov/iTable/index_industry_io.cfm

In previous reports, the Council identified the need for the public and private sectors, as well as civil society, to further converge.
Source: See World Economic Forum, The Future of Manufacturing: Driving Capabilities, Enabling Investments, 2014.
https://www.weforum.org/reports/future-manufacturing-driving-capabilities-enabling-investments
See World Economic Forum, Enabling Sustainable Global Manufacturing, 2012.
http://www3.weforum.org/docs/WEF_GAC_EnablingSustainableGlobalManufacturing_Report_2012.pdf

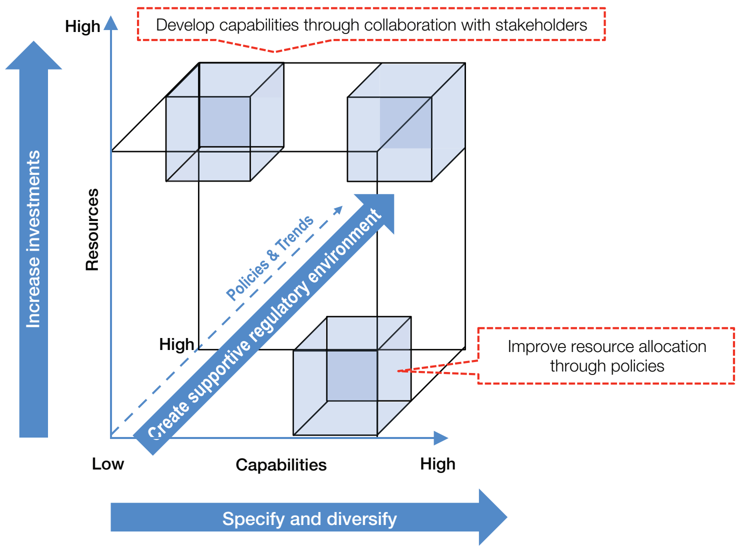
It also pointed to areas of focus on convergence (Figure 1) and divergence, and identified future scenarios for different countries.

However, several key questions remained to be addressed:
- What is the experience of governments, the private sector and civil society in addressing challenges related to the future of manufacturing?
- Which policies or solutions were put forward?
- What was their level of effectiveness?
- Which lessons can be retained?

Nine pillars of manufacturing capabilities build the basis for transforming and changing the sector. Manufacturing's future relies on developing capabilities – the attributes of organizations, industries and countries that add value in an economy. A series of nine pillars (details in Appendix 4) influences manufacturing capabilities, providing the basic means for the current drivers of manufacturing to transform and change the sector in the future, as highlighted in the next chapter.

***This White Paper focuses on case studies and experience by sector, drivers or countries that can help inform on where the "future of manufacturing" is headed, and address key questions*.** The case studies deal with important drivers of change, including industrial policy 2.0, innovation, value chains, capital and finance, big data, the circular economy, skills, infrastructure and "servicification". They include energy-based economies; least developed, developing and developed economies; and countries of the Organisation for Economic Co-operation and Development (OECD). The White Paper's framework highlights the case studies to help address the questions.

Figure 1: Convergence Framework



Source: Global Agenda Council on the Future of Manufacturing, Whiteshield Partners framing

Cases Studies on the Future of Manufacturing

Identifying key drivers

As prior inquiries by the Global Agenda Council on the Future of Manufacturing have underlined, manufacturing has become so complex that to ensure its effective development, the interests of the private sector, public sector and civil society must often converge.

The Council also identified 10 key drivers that are shaping the future of manufacturing (Figure 2; and, see Appendix 3 for detailed definitions).

Integrating the impact of the possible fourth industrial revolution

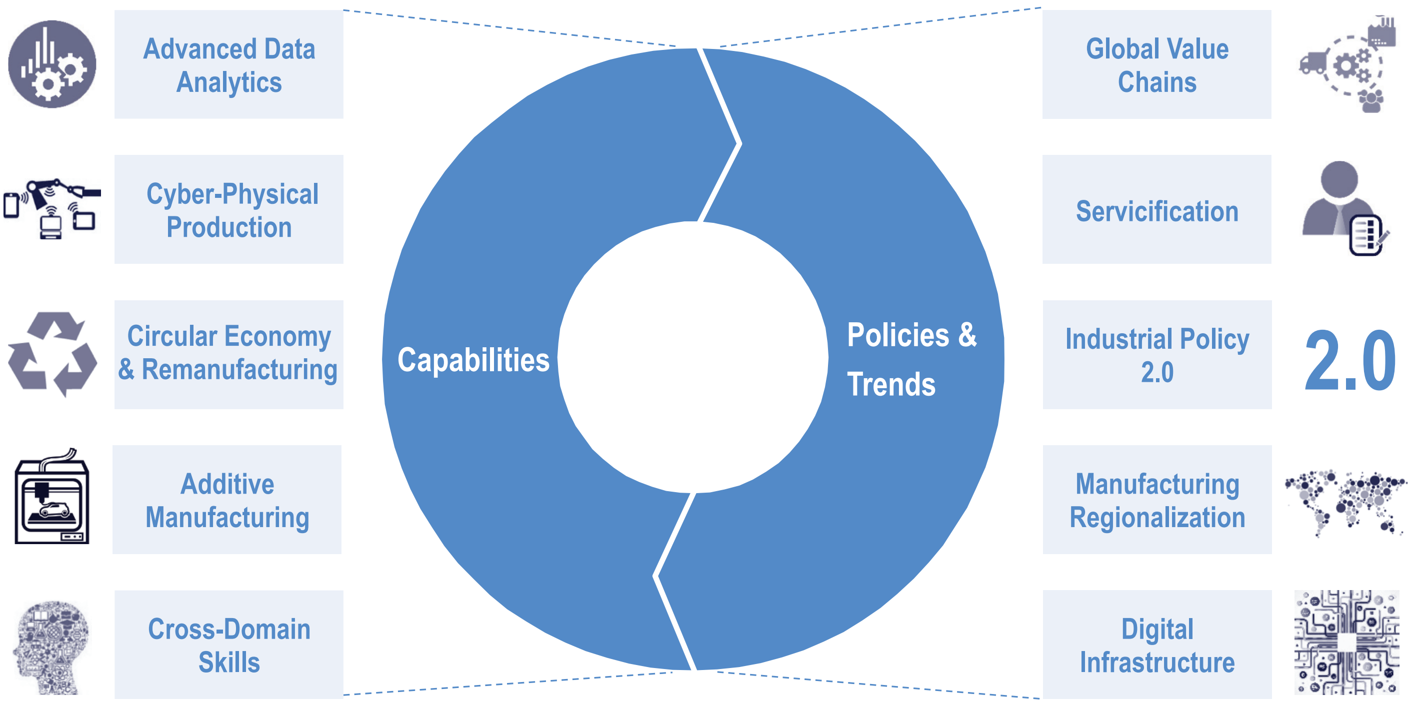
Beyond key drivers, the Forum also identified a broader shift in manufacturing – the fourth industrial revolution – that will impact the sector's future. Industrial revolutions come in waves or cycles of technological innovations (Avent, 2014), creating new opportunities for manufacturing, and they have become increasingly complex (Figure 3). The original Industrial Revolution began in the 1780s and was based on water and steam as sources of mechanical energy, while the second, in the 1870s, featured electric power in production. Currently, the world is transitioning from the third industrial revolution, which started in the 1960s with the use of information systems and automation, to the fourth, which is characterized by a convergence of capabilities and policies (Davis, 2015; Schwab, 2015).

The fourth industrial revolution stands out from the previous waves of technological diffusion with an unprecedented exponential pace and broad scale of change. Business and government leaders have to reassess their market positioning and preparedness for the disruptions likely to follow (Schwab, 2015). Figure 3 summarizes the steps in moving towards the fourth industrial revolution. A better understanding of the underlying dynamics can help manufacturing companies maintain competitive advantages or seize new opportunities.

Learning from experience: clustering case studies around key drivers and types of economies

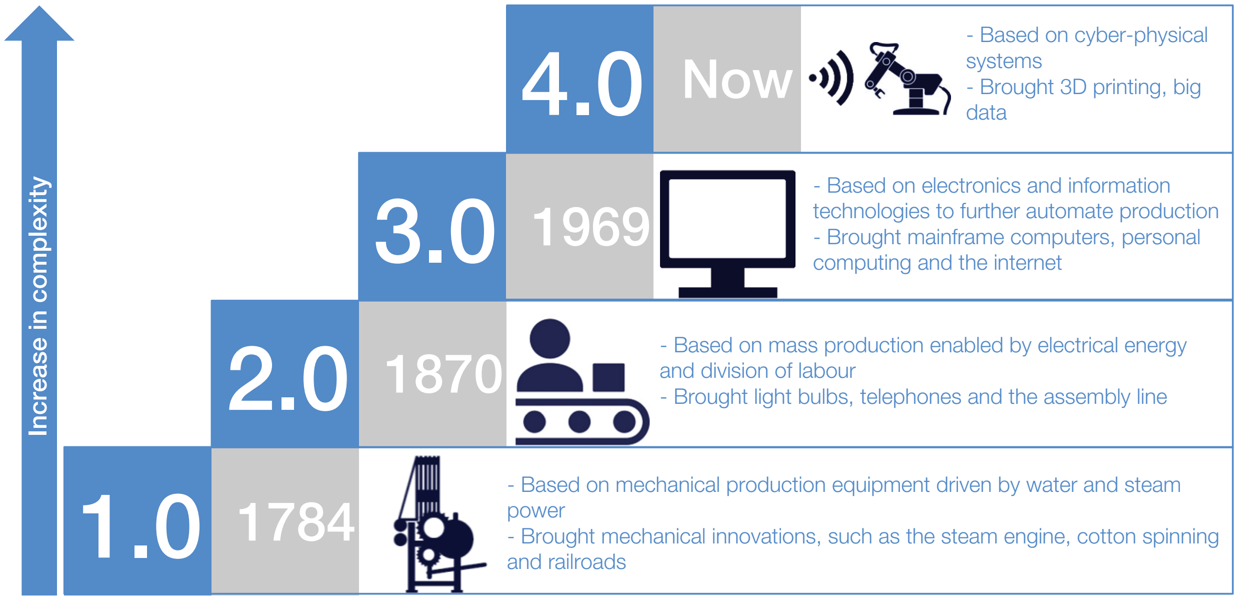
The White Paper provides a selection of case studies (Figure 4) based on combining the drivers of the future of manufacturing, the impact of the potential fourth industrial revolution and the clusters of countries. The case studies can help inform both policy-makers and the private sector about future trends and successful experiences.

Figure 2: Drivers of the Future of Manufacturing



Sources: Global Agenda Council on the Future of Manufacturing, Whiteshield Partners framing

Figure 3: Evolution of the Four Industrial Revolutions



Sources: Global Agenda Council on the Future of Manufacturing, Whiteshield Partners framing

Figure 4: Case Studies by Driver and Region

Region	Driver									
	Advanced Data Analytics	Cyber-Physical Production	Circular Economy & Remanufacturing	Additive Manufacturing	Cross-Domain Skills	Global Value Chains	Servicification	Industrial Policy 2.0	Manufacturing Regionalization	Digital Infrastructure
Least Developed Economies	2, 7, 21	7, 21	2	7, 21	2, 14, 1, 21	14	14	2, 14, 1, 21		7, 21, 1
Energy-based Economies	7, 21	7, 19, 21		7, 21	7, 19, 21	19, 12	12	1, 19, 21	12	1, 7, 12, 21
Developing Economies	7, 9, 11, 21	6, 7, 21	4, 9	4, 7, 21	4, 6, 5, 9, 15, 21, 1	3, 4, 6, 9, 11, 12, 5, 15	12, 15	3, 4, 6, 11, 21, 15, 1, 5	3, 6, 9, 11, 5, 15	9, 7, 12, 15, 1, 21
Developed Economies or OECD Countries	7, 9, 11, 21, 11	7, 16, 21	8	7, 21	1, 10, 13, 15, 16, 17, 18, 20, 21	8, 10, 13, 15, 18	15	8, 13, 15, 18, 21, 1	15, 10, 13	7, 15, 1, 21

1. Framing the Future of Manufacturing Policies: A Country Case Study
2. Bangladesh Low-Carbon Zones
3. Brazilian Technological Trajectory in the Pharmaceutical Industry
4. China's Manufacturing Successes and Pitfalls
5. Civil Society Advocacy for Better Treatment of Migrant Workers in Malaysian Electronics Production
6. Long-Term Public Funding Support in Capital-Intensive Global Industries
7. Emerging and Disruptive Technologies for the Future of Manufacturing
8. Success of the Circular Economy of Automotive Battery Recycling
9. Vietnam Mobility Study
10. Accelerating the Growth of Small and Medium-Sized Aerospace Enterprises in the Rockford, Illinois Region
11. Costa Rica Medical Devices
12. Logistics at the Crossroads: Panama and Dubai
13. Pilot Czech Supplier Development Programme Electronics and Automotive
14. Rwanda Coffee Sector
15. Suzhou Industrial Park – Integrating Drivers of Competitiveness to Boost Global Value Chain Participation
16. Central Piedmont Community College
17. Engineer in Residence Programme
18. Skilling the Bay Workforce Training Strategy
19. Strata Manufacturing: Working to Empower Emiratis and Women of the UAE
20. Training and Internship Programme for PD Athlone
21. Thought Piece on the Future of Manufacturing Know-How in Automotive

Sources: Global Agenda Council on the Future of Manufacturing, Whiteshield Partners framing

E-Library of Case Studies

Please click the links below to access each case study

National and Industrial Policy	Value Chains
1. Framing the Future of Manufacturing Policies	10. Accelerating the Growth of Small and Medium-Sized Aerospace Enterprises in the Rockford, Illinois Region
2. Bangladesh Low-Carbon Zones	11. Costa Rica Medical Devices
3. Brazilian Technological Trajectory in the Pharmaceutical Industry	12. Logistics at the Crossroads: Panama and Dubai
4. China's Manufacturing Successes and Pitfalls	13. Pilot Czech Supplier Development Programme in Electronics and Automotive
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Advanced Technology	Skills Development
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Please click here for the white paper references

Conclusion: Past Recipes Cannot Apply to the Future

A call for further convergence of interests and a new industrialization development language

The case studies highlight the importance of developing new skills as a pillar of future manufacturing. For these skills to be more effective, their development should draw on local factors as well as on a convergence of visions and interests. This convergence and new vision are the base for new industrial policies that can upgrade a country's position in global value chains.

This White Paper points out three important areas for policy-makers, business and civil society alike:

1. **Public- and private-sector interests need to converge**, which highlights the need for new industrial-policy collaboration models, starting with new skills development models.
2. **A new "manufacturing" language must focus on capabilities and global value chains** beyond the typical gross domestic product measures, in order to anticipate underlying constraints on industrialization.
3. **New, connected business industrial models can help prepare for the potential fourth industrial revolution**.

However, the conclusions here are only an initial direction that requires further discussion and research between the public and private sectors to address other key questions:

- How can further convergence of the public and private sectors, as well as civil society, be promoted?
- How can multiple policy initiatives and instruments be aligned in one direction (e.g. supplier development programmes, promotion of foreign direct investment, upgrading infrastructure, skills development)?
- At what pace have countries and businesses adapted to the changing manufacturing environment?
- How should industrial policies be focused to match the development of future capabilities?
- How can countries effectively move up the value chain and focus on what should be "produced" versus "sold"?

Any interested party is invited to contribute to the debate on this platform.

Appendices

Appendix 1: Reflections Based on the Working Session of the Global Agenda Council on the Future of Manufacturing

Besides identifying the key drivers and selecting case studies about successes in transforming manufacturing, the Council engaged with the World Economic Forum Meta-Council on the Circular Economy in a cross-industry and multistakeholder workshop in Abu Dhabi, United Arab Emirates, in November 2015. The meeting convened experts in manufacturing with representatives from government to explore major transformations, disruptions and policy implications. The discussion highlighted the importance of key areas shaping the future of manufacturing: innovation and technology, human capital and skills, supply chain integration and the circular economy. All four are closely linked where new technologies, innovation and digitization will have a critical impact not only on the manufacturing environment and how governments design their policies in a global context, but also on manufacturing as a driver of economic growth and job creation in a competitive environment.

New ways of thinking

Innovation and technology

To be at the forefront of innovation, governments have to consider building disruptive technology applications (rather than importing them) by developing a culture for entrepreneurship and innovation. Increasing research and development (R&D) to reach goals on innovation also requires institutional changes that lead to a robust system of protecting intellectual property as a key driver. Policies play a crucial role in providing incentives to the private sector to invest in technological innovation and encourage R&D. Today, large companies invest up to 20% of their revenue in R&D. Additional levers that require smart policies involve attracting talent from around the world, encouraging industries and universities to collaborate, and funding innovative small-business research. The overall strategy for building an innovative and technology-driven manufacturing sector should include finding a balance between mission-driven innovation and innovation based on curiosity.

Human capital and skills

The challenge of having attractive manufacturing jobs comes from two angles: competition and preference. To make manufacturing appealing, programmes must be designed to promote the sector. For example, a Global Manufacturing Day in the United States provides outreach to 500,000 students so they can visit factories. Top leaders need to support efforts to ensure diversity and inclusion, providing visible role models for under-represented groups. Nevertheless, it takes many years to educate a highly skilled worker. While education must be relevant to the economic opportunity, a four-year degree may not be relevant. Many countries and regions try to reimport talent that has left in an attempt to shift from "brain drain" to "brain boomerang". A strategy is needed for attracting experts to return to local industries after they have worked overseas. In addition, assurance is required that people's existing skills can be "translated" into job classifications in other sectors and among other employers. New digital platforms can align skills and requirements, thereby translating foundation-level competencies and capabilities into job specifications. Focusing on and strengthening soft skills, including problem-solving and skills in liberal arts and creative arts, help workers to keep a job after acquiring technical qualifications.

Supply chain integration

Countries with an advantageous geographic location and a strong, developed logistical sector can benefit from technology employed through established logistics services hubs to integrate local supply chains into global value chains. Moreover, manufacturing supply chains can be used as tools of competitiveness by providing a platform for an expanded competitive proposition within the manufacturing value chain. By regionalizing global production systems, innovations, such as 3D printing, could evolve as descaling devices. They would have an impact on the logistics business, local small to medium-sized enterprises (SMEs) and integration into global value chains. By assessing and improving local capabilities, SMEs can integrate into global value chains as anchors for logistics and manufacturing. Government incentives developed to keep upstream and downstream logistics competitive can become measures for a global benchmark.

The circular economy

In tackling the constraint of finite resources, the circular economy creates a model through which society produces only what people need and creates restorative loops. Increasing the use of assets and products so that they reach their highest value typifies this type of economy. Compared to looking at an economy via today's linear system, viewing it through a circular lens across the entire life cycle changes the production value chain's philosophy from "design" to "disposal". Take a washing machine, for example: consumers should pay per wash rather than pay for the machine itself, thus maximizing its use. At the end of its functional life, a recycling process disassembles the equipment into the original materials for reuse. The entire economic system is being reassessed, placing manufacturing and material sciences at its centre.

Policy implications

The dichotomy of manufacturing as a global activity versus policies developed on a national level has created a gap. Countries need to take globalization and global competitiveness into account when creating policies. Today, capabilities rather than resources constitute the limiting factors. Why should industries be built at a certain location in a world where raw materials and finished goods are easy to move around? The availability of collective know-how is a major concern: such know-how is difficult to obtain, as it has more to do with on-the-job training than with education. The labour force's depth and liquidity are critical factors and determine where companies decide to locate. With migration as an enabling factor, policies must address the shift of focus from resources to capabilities for the manufacturing sector to flourish.
Source: Global Agenda Council on the Future of Manufacturing – "The Future of Manufacturing – A Workshop in Cooperation with the United Arab Emirates", 2015.

Appendix 2: Why Manufacturing Matters – Definitions

Source: Whiteshield Partners

Job Engine

Manufacturing generates jobs for both highly skilled and low-skilled workforces. As manufacturing jobs are generally considered more productive than those in other industries, wages are on average 8% higher when controlling for education and other job characteristics (Helper, Krueger & Wial, 2012; UNIDO, 2013a). Global employment in manufacturing has increased from over 210 million in 1970 to 388 million in 2009 (UNIDO, 2013a). However, these numbers are severely understating the sector's true impact on overall employment. Effectively, manufacturing has increasingly stimulated manufacturing-related service jobs over the last decades through outsourcing (e.g. warehousing, transportation, information technology services) and product bundling (e.g. maintenance and repair service, retail services) (McKinsey Global Institute, 2012). Remarkably, every 100 jobs created in manufacturing help to create an additional 250 jobs in related sectors (Deloitte & Manufacturing Institute, 2015). Therefore, the number of global manufacturing-related jobs is much higher, with 470 million in 2009 reflecting 16% of total global employment (UNIDO, 2013a). Nonetheless, employment growth in manufacturing was not uniformly distributed across regions. Developing countries saw an increase in manufacturing employment due to a higher demand for products, a more highly skilled workforce and an influx of foreign direct investments. However, advanced economies, such as the United States, the United Kingdom and Germany, experienced a decline in manufacturing employment (Helper et al., 2012; Levinson, 2012) relative to total employment between 2000 and 2014 (-4.3% on average) (OECD, 2015). The two main factors driving this development have been (1) the outsourcing of labour-intensive and highly tradable industries (e.g. electronics production, apparel) from advanced economies to developing economies, and (2) productivity increases from automation and technological advances during the third industrial revolution. This employment dynamic is characteristic of the manufacturing industry and follows an inverted "U" curve when comparing it to the development of gross domestic product (GDP) per capita. Importantly, this relationship does not capture manufacturing-related service jobs.

Economic Growth

Manufacturing is fundamental to economic growth because it offers more opportunities than other economic sectors to increase productivity. Particularly its ability to accumulate capital, to benefit from economies of scale, and to acquire and diffuse new technologies make it an important backbone of an economy. Globally, manufacturing accounts for 16% of GDP (McKinsey Global Institute, 2012; UNIDO, 2013a; Szirmai, Naudé & Alcorta, 2013). Beyond that, manufacturing output stimulates an economy as a whole (Kaldor's first law) (Marconi, de Borja Reis & de Araújo, 2016) due to the multiplier effect it has on other sectors. Owing to the complex production processes in manufacturing, output in the sector increases the demand for a large set of industries, such as raw materials, construction, services, transport and insurance. The backward linkage of the manufacturing sector, in particular, spurs overall economic growth: every $1 in sales of manufactured goods supports $1.33 of output from other sectors. This multiplier effect is the largest among all sectors (Manufacturing Institute, 2015; UNIDO, 2013a). Finally, manufacturing represents 70% of global trade (McKinsey Global Institute, 2012) and, thus, significantly influences an economy's trade balance (Baily & Bosworth, 2014).

Source of Innovation

No other industry is so exposed to global competition as is manufacturing. Many manufacturing companies are thus constantly looking at new avenues to sustain or create comparative advantages by adopting new technologies, innovating products and processes, or increasing cost-efficiency. As a consequence, the sector's companies were three times more likely in 2006-2008 to introduce a new or significantly improved good or service and to use a new production or distribution method. Beyond that, the manufacturing sector has the highest business enterprise R&D expenditure ratio compared to other sectors. A main driver of technology development and further innovation, the ratio is 57% on average in the OECD and as high as 90% in selected economies (Helper et al., 2012; McKinsey Global Institute, 2012; OECD, 2013b; UNIDO, 2013a).

Environmental Sustainability

Although the manufacturing sector is responsible for 22% of total greenhouse gas emissions (electricity, gas and water about 26%; private households 20%) (European Environment Agency, 2013), it can be considered as the main sector contributing to environmental sustainability. Technological products indispensable for the clean economy are highly manufacturing-intensive (e.g. solar panels, windmills, CO_2 filters, energy-saving ventilation, air conditioning appliances) (Muro, Rothwell & Saha, 2011). For instance, over 90% of all jobs in electric vehicle technologies, water-efficient products, green chemical products, energy-efficient appliances, sustainable forestry products, lighting, recycled-content products and energy-saving consumer products are in manufacturing (Helper et al., 2012).

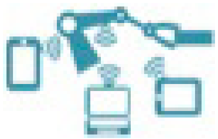
Appendix 3: Drivers of the Future of Manufacturing

Source: Whiteshield Partners

Advanced Data Analytics

Advanced data analytics allow for applying mathematical tools and statistics to business data (e.g. historical production process data). The objective is to identify patterns and relationships. Insights generated from such analytics allow operations managers to reduce waste and variance in the production process, or improve product quality (Auschitzky, Hammer & Rajagopaul, 2014). Big data enables the processing and making of predictive analytics with datasets previously considered as too large and complex. This development is marked by ever increasing *volumes* of data (the amount of data collected from the beginning of time to the year 2000 represents the amount of data collected every minute today) from a greater *variety* of sources (e.g. sensors) and with increased *velocity* (e.g. big data technology can now analyse data without storing it in databases) (IBM, 2014). Big data has become feasible because of advances in computer power and improved software. These advances can benefit manufacturing companies through 20-50% lower R&D costs from the ability to develop digital prototypes before building physical ones, and a faster time to market (Baily & Bosworth, 2014).

Cyber-Physical Production



Cyber-physical production (CPP) represents a collaborative system integrating computers, networks and physical elements. The Internet of Things (IoT) is essential for this because it connects objects (e.g. sensors) and machines with each other over the internet (PwC; Manufacturing Institute, 2015). The technology provides an array of new opportunity for the factory of the future, such as (i) monitoring production processes remotely; (ii) having production systems adjust automatically based on sensor readings, improved efficiency (e.g. energy usage) (Baily & Bosworth, 2014) or decreased failure output; and (iii) using machines that automatically replenish stocks across the supply chain (Löffler & Tschiesner, 2013). Overall, CPP will allow for an interconnected manufacturing value chain in the future built on information and communications technologies (KPMG, 2014). In turn, CPP reinforces the potential of advanced data analytics through an increased volume of new data provided by the network of connected objectives (Chui, Löffler & Roberts, 2010; Lee, Lapira, Bagheri & Kao, 2013).

Circular Economy and Remanufacturing

Finite resources not only drive the manufacturing sector to improve its resource consumption, but also contribute to building a circular economy that preserves natural resources, enhances resource yields and reduces systematic risks by actively managing the supply cycle (Ellen MacArthur Foundation; McKinsey Center for Business and Environment, 2015). The circular economy changes the paradigm from disposability to restoration, requiring manufacturers to design products for multiple cycles of disassembly and reutilization (McDonough & Braungart, 2002). New skills are then needed in the remanufacturing field (e.g. designing products for optimized dismantling and recycling), which already accounts for 1 million jobs in Europe and the United States (Nguyen, Stuchtey & Zils, 2014; The Economist, 2013). The circular economy provides the opportunity for manufacturers to increase value added while also mitigating supply risks and demand-driven volatility; for example, in the automotive, machining and transport sector, global materials savings could be as high as 170 million metric tons of iron ore annually by 2025 (Nguyen et al., 2014).

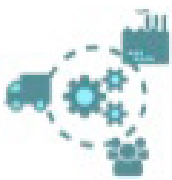
Additive Manufacturing

Additive manufacturing, like 3D printing, differs from conventional subtractive machining processes that rely on removing material by cutting or drilling. Instead, 3D printing creates objects by successively adding layers of material, ranging from plastic and metal to ceramic. In turn, these layers are bound by heat or chemicals. Additive manufacturing is currently transitioning from an expensive niche for fast prototyping to the mass market in various industries, such as automotive, aerospace or medical technology (Baily & Bosworth, 2014; KPMG, 2014). The advantages for the manufacturing sector include faster and more flexible R&D, higher degrees of customization (e.g. lot size 1), and reduction in waste and the size of inventories (UNIDO et al., 2013). The challenge will be to develop a comprehensive set of design principles and standards for additive manufacturing to ensure widespread adaption in the sector (Gao et al., 2015). Furthermore, 3D printing could disrupt global supply chains. Manufacturing's future may consist of a global network of 3D printers with higher customer proximity, which means logistics will be about delivering digital design files rather than parts. This has important implications for employees' required skills. Blue-collar workers need to learn how to handle the technology and thus become "shaded-collar workers". Consequently, cost advantages of countries with low labour costs will diminish and give rise to backsourcing (PwC & Manufacturing Institute, 2014a).

Cross-Domain Skills

The future of manufacturing will see an increased demand for cross-domain skills covering technology, engineering, electronics, robotics, usage of new equipment, computational thinking, coding and computer sciences (Deloitte & Manufacturing Institute, 2015; KPMG, 2014; Hagerty & Shukla, 2015). The typical blue- vs white-collar job distinction does not hold anymore. While former white-collar workers have moved up into innovation, former blue-collar workers are required to perform more capability and cross-domain-based functions in manufacturing, as machines take over manual jobs (Davies, Fidler & Gorb, 2011)CA","page":"19","event-place":"Palo Alto, CA","author":[{"family":"Davies","given":"Anna"},{"family":"Fidler","given":"Devin"},{"family":"Gorb","given":"Marina"}],"issued":{"date-parts":[["2011"]]}}}],"schema":"https://github.com/citation-style-language/schema/raw/master/csl-citation.json"} . Soon, industrial robots will not only perform repetitive tasks such as welding and material handling, but also become smarter (e.g. sensing capabilities, increased dexterity, ability to memorize and train), faster and cheaper (PwC & Manufacturing Institute, 2014b). Thus, the era of shaded-collar workers starts, today, with a convergence in domain learning adapted to new technologies and materials. A lack of cross-domain skills will be a significant competitive disadvantage in manufacturing's future. Therefore, vocational training, on-the-job training (reskilling and upskilling), as well as recruitment from a wider talent pool, are of increasing importance for manufacturing companies (Deloitte & Manufacturing Institute, 2015; PwC & Manufacturing Institute, 2014b; World Economic Forum, 2016).

Global Value Chains



International trade and manufacturing are increasingly structured around global value chains (GVCs). A GVC "involves all the activities that firms engage in, at home or abroad, to bring a product to the market, from conception to final use. Such activities range from design, production, marketing, logistics and distribution to support to the final customer" (OECD, 2013c). Globalization, reduced logistics costs, trade policy reforms, specialization of countries in tasks instead of in products, and a network of global buyers and suppliers have led to further international fragmentation (length) of GVCs based on countries' comparative advantages (OECD, 2012). Today, already over 50% of globally manufactured imports are intermediate goods. Thereby, television and communication equipment, motor vehicles, basic metals, electrical machinery and textiles, and leather and footwear exhibit the highest degree of GVC fragmentation (Cattaneo, Gereffi, Miroudot & Taglioni, 2013). Besides efficiency gains and the potential for competitive specialization, the spread of GVCs provides opportunities for manufacturing companies to acquire new knowledge. Therefore, GVCs represent a fundamental source of economic upgrading for countries, regions and companies (Gereffi & Fernandez-Stark, 2011).

Servicification

Servicification is the trend of increasing purchases, production, sales and exports of manufacturing services (Lodefalk, 2015; Pilat, Cimper, Olsen & Webb, 2008). Today, services account for 40% of world trade when considering services embodied in exported manufactured goods (Lanz & Maurer, 2015). Mature manufacturing regions in particular saw an increase in manufacturing services because of saturation in the sector (commoditization of fabrication) and the desire to differentiate in light of growing global competition (Baldwin, 2015). The future of manufacturing will see more service-driven manufacturing business models as customers increasingly demand more added value (McKinsey Global Institute, 2012). This requires manufacturers to change from product-focused business models to those that are client-centric (KPMG, 2014). Since the export intensity of manufactured goods increases with growth in related services, trade policies for goods and services become more important to ensuring the manufacturing sector's competitiveness (Baldwin, 2015; Lodefalk, 2015). Moreover, as services in manufacturing become more commoditized, manufacturers have to look at new avenues for creating above-average competitive advantages by combining manufacturing services and big data (Opresnik & Taisch, 2015).

Industrial Policy 2.0

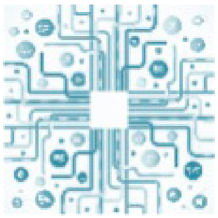
2.0

Industrial policy has shifted from mainly product market interventions (e.g. subsidies, tariffs) and market failure correcting instruments (e.g. corrective taxes, access to finances, R&D incentives) to a focus on building an enabling framework for economic development, facilitating networks, developing institutions and coordinating aligned strategic priorities (Gur*ría,* 2013; OECD, 2013a). The new set of Industrial Policies 2.0 avoids the pitfall of "picking winners" from the previous functional and horizontal Industrial Policies 1.0 (World Bank, 2005). Instead, new industrial policies leverage private resources by concentrating investments on key priorities based on regions' comparative advantages and target activities, and not on sectors, which exhibit potential positive spillover effects (Rodrik, 2004). This requires that private and public agents closely collaborate on the design of industrial policy (Haque, 2007; Rodrik, 2008). Instruments include cluster policies, promoting investment, public procurement and encouraging green growth (OECD, 2013a).

Manufacturing Regionalization

Two primary trends in manufacturing regionalization shape the future of manufacturing. First, diminishing labour-cost advantages in developing countries make it more attractive for manufacturers to nearshore production to countries that are closer not just geographically but also in cultural characteristics and economic structure, in order to benefit from higher levels of control and mitigated costs of doing business (KPMG, 2014). Second, the concentration of manufacturing companies and related suppliers, customers, R&D institutions and universities in close geographical clusters is likely to increase. They enable higher degrees of knowledge spillover, specialization and shared infrastructure, and may provide competitive advantage by accelerating technological innovation and gains in efficiency (KPMG, 2014; Pisano & Shih, 2009).

Digital Infrastructure



Well-functioning digital infrastructure is the foundation of manufacturing's future, and is indispensable for realizing gains in productivity and efficiency. Today, already 4.9 billion objects are interconnected through the IoT; by 2025, that number will grow to 25 billion (Gartner, 2014). In particular, the spread of sensors, low-cost computing, electronics and digital storage will expand the digital infrastructure. This will likely both disrupt incumbent manufacturing companies as well as create an array of new opportunities. First, advances in digital infrastructure (e.g. knowledge stored in clouds, downloadable production designs, digital sourcing and sales platforms) reduce barriers for new market entries and require incumbents to constantly innovate. Second, digital infrastructure reduces the distance between manufacturers and customers, thereby reducing dependency on intermediaries. Finally, such infrastructure enables the sharing economy, which triggered new business models such as ride sharing (Uber) or crowdsourced housing (Airbnb). In the same way, digital infrastructure creates the opportunity for manufacturing companies to reinvent products so that they leverage the potential of digital service (Hagel III et al., 2015). As a consequence, investments in maintaining such infrastructure and making it more sophisticated will become critical for countries and companies to keep up with global competition (World Economic Forum, 2012b).

Appendix 4: Key Manufacturing Pillars Identified by the Global Agenda Council on the Future of Manufacturing

The nine pillars that influence manufacturing and its context are:

Skills

Manufacturing has historically relied on developing skills, which in turn has promoted its capabilities. Individuals in the sector's workforce possess skills (acquired through formal education, training or experience), which are critical assets because they add value to the manufacturing process. Entrepreneurial skills are also relevant, as they commonly help to set up new ventures that at times lead to new products and processes.

Actors involved in all the processes supporting manufacturing, including design, marketing, finance, technology, human resources, operations and law, must be able to interact and combine their knowledge to make products. If these interactions are ineffective, or if some actors are either not present or have limited skills, manufacturing capabilities are hindered and limited to specific ranges of activities. However, technological and commercial developments are challenging the acquisition, expansion and retention of skills and capabilities. Outsourcing and offshoring are commonly associated with a transfer of the skill base to new locations. Further, automation is making some skills obsolete or redundant.

Innovation

Innovations can lead to new materials, products, processes and services, and are often responsible for creating entirely new manufacturing sectors or industries. Innovation is essential for economic development and to create wealth; it relies heavily on entrepreneurship, creativity and skills, as well as R&D, in a dynamic environment supported by the public and private sectors.

Technological innovation and economic growth are closely related, but innovation is always disruptive. It makes some existing products and processes obsolete, including many associated with employment, while new sectors being promoted will create new products and employment opportunities. Innovation's increasing complexity, however, is a challenge given the capabilities of industries and regions to encourage it. In the past, innovation was usually associated with increasing economic and employment opportunities. While it will most likely provide future benefits in manufacturing productivity and efficiency, employment benefits are less evident.

Infrastructure

Infrastructure refers to the built environment of an economy, including highways, railroads, seaports, airports, energy, public transit, telecommunications, real estate and equipment. Infrastructure is critical not only as the accumulation of capital stock, but also for the connectivity it provides between sets of producers and consumers.

Infrastructure that supports manufacturing has been effectively developed since the Industrial Revolution, as areas related to port, rail and road infrastructure emerged to become manufacturing clusters. Globalization has underlined the need for high-capacity and efficient infrastructure, particularly telecommunications (web-based), which has become an important factor in logistical connectivity and competitiveness. The challenge remains about what is the proper mix and provision of infrastructure to support different manufacturing sectors, and how this infrastructure is financed and maintained.

Capital

Banks, corporations or third parties provide financial resources (i.e. debt or equity) to enable the setting up, operation, changes to and expansion of new manufacturing institutions. Many industries, such as high technology, have long-established relationships with capital providers, namely venture capital.

In a well-functioning manufacturing sector, financial resources are made available at internationally competitive conditions to a wide range of economic actors. Political volatility and fluctuations in exchange rates can undermine the availability of capital, which impacts opportunities to develop manufacturing. Investment capital in manufacturing is also competing with other sectors and tends to accumulate in activities estimated to have the highest rates of return. Manufacturing's capital intensity is likely to increase as it moves further towards automation.

Markets

Markets link supply and demand in manufacturing. On the demand side, markets refer to consumption (which is related to consumer purchasing power) in both its existing and potential size and sophistication. On the supply side, market competition refers to the existing capacity to meet demand, including its seasonality and the competition that drives corporations towards manufacturing. It also includes a variety of suppliers of goods and services for the manufacturing sector.

Regarding demand, a series of socioeconomic changes is challenging the global market. On the positive side, standards of living and, thus, purchasing power, have improved substantially, particularly in developing economies. However, the global population is also ageing, and that is changing consumption patterns. Further, standards of living in developed countries appear to be peaking, affecting future prospects for the consumption of manufactured goods. On the supply side, the risk of monopolies or oligopolies may impair innovation and improvement in manufacturing efficiency. Sufficient competition is needed to induce efficient production and pricing among firms, along with innovation to create new sources of wealth and value.

Value Chains

Contemporary manufacturing has evolved from a system of isolated factories as the centerpieces of production towards international production networks that link firms and countries. These networks are complex value chains, ranging from being global to local. The value chains determine where value is created and distributed, who captures and controls it, and the conditions under which buyers, suppliers and intermediaries in the system can generate growth and improve productivity.

Technological, regulatory and market changes have an impact on value chains, and trends influence design, innovation, fabrication and distribution. Reshoring and nearshoring will affect the nature of and extent to which outsourcing and offshoring of activities will occur for value chains to grow. A country's capacity to logistically support networks of firms that are segregated by space or distance will also influence value chains.

Policy

Macroeconomic policy includes statements, guidelines, norms and instruments related to interest rates, exchange rates, wages, benefits, immigration and administrative procedures. These significantly affect firms' ability to engage in capabilities-oriented manufacturing. Microeconomic policy refers to statements, guidelines, norms and instruments related to trade, innovation, industrial production in particular sectors, land use, and incentives or penalties related to certain kinds of economic behaviour by firms.

Public policy is shifting its attention from promoting competitiveness in terms of decreasing costs to developing capabilities that focus on increasing manufacturing's value added. A number of large emerging economies have a growing interest in using industrial policy to affect particular groups of producers or consumers, in line with economic and political goals. Policy is commonly a double-edged sword because it also has unintended consequences. Will the future political context favour protectionist policies, or will liberalization continue to strongly influence global manufacturing?

Society

Societal factors include demographic characteristics, as well as educational and income levels, of the workforce and consumers; a country's level of economic development; and its political, social and cultural institutions and values. These factors will affect how quickly and extensively capabilities-oriented manufacturing takes hold. Society also includes a wide array of advocacy groups, such as non-governmental organizations and labour unions.

Society needs to provide an environment that enables manufacturing to achieve its goals, as well as the ability to improve a nation's social capital.

Environment

Shaping manufacturing's future requires an awareness of environmental constraints and vulnerabilities, as well as a commitment to address both from planetary and social perspectives. Manufacturing must minimize its environmental impact for society to achieve sustainable development. Moreover, an economy's product and material flows need to be designed to restore or recycle materials used in production, delivery and recycling.

Clean technologies that refocus the use of rare and high-energy-consuming resources are becoming an important source of sustainable growth and innovation in manufacturing.

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