Briefing

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Industry 4.0

Digitalisation for productivity and growth

SUMMARY

Many observers believe that Europe is at the beginning of a new industrial revolution, considered to be the fourth such leap forward and hence labelled Industry 4.0. The ubiquitous use of sensors, the expansion of wireless communication and networks, the deployment of increasingly intelligent robots and machines – as well as increased computing power at lower cost and the development of 'big data' analytics – has the potential to transform the way goods are manufactured in Europe.

This new, digital industrial revolution holds the promise of increased flexibility in manufacturing, mass customisation, increased speed, better quality and improved productivity. However to capture these benefits, enterprises will need to invest in equipment, information and communication technologies (ICTs) and data analysis as well as the integration of data flows throughout the global value chain.

The EU supports industrial change through its industrial policy and through research and infrastructure funding. Member States are also sponsoring national initiatives such as *Industrie 4.0* in Germany, the Factory of the Future in France and Italy, and Catapult centres in the UK. However challenges remain. The need for investment, changing business models, data issues, legal questions of liability and intellectual property, standards, and skills mismatches are among the challenges that must be met if benefits are to be gained from new manufacturing and industrial technologies. If these obstacles can be overcome, Industry 4.0 may help to reverse the past decline in industrialisation and increase total value added from manufacturing to a targeted 20% of all value added by 2020.

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Context

The industrial sector is important to the EU economy and remains a driver of growth and employment. Industry (which in this context means manufacturing and excludes mining, construction and energy) provides added value through the transformation of materials into products. Although only roughly 1 in 10 enterprises in the EU is classified as manufacturing, the sector comprises 2 million companies and is responsible for 33 million jobs. It is also responsible for over 80% of exports and 80% percent of private research and innovation, and as such is one of the key elements of sustainable economic growth. Moreover, every new job in manufacturing results in the creation of between one half and 2 jobs in other sectors.[1]

However the relative contribution of industry to the EU economy is declining. The European economy has lost a third of its industrial base over the past 40 years. By the third quarter of 2014, the value added by manufacturing to the economy in the EU represented only 15.3% of total value added, a decline of 1.2 percentage points since the beginning of 2008. This 'de-industrialisation', a process which is also present in other developed economies, is in part due to the rise of manufacturing in other parts of the world (notably China), the relocation of labour-intensive work to countries with lower labour costs and global supply chains with suppliers located outside the EU. Moreover, the growing services sector represents an ever-larger proportion of the total European economy, resulting in a lower relative share for industry.[2]

In 2012, in response to this decline in the relative importance of industry, the European Commission set a target that manufacturing should represent 20% of total value added in the EU by 2020. Whilst some observers find this goal overly ambitious, many believe that we are on the brink of a new industrial revolution, Industry 4.0, which could boost the productivity and value added of European industries and stimulate economic growth. As part of its new Digital Single Market Strategy, the European Commission wants to help all industrial sectors exploit new technologies and manage a transition to a smart, Industry 4.0 industrial system.

What is Industry 4.0?

Industry 4.0 is a term applied to a group of rapid transformations in the design, manufacture, operation and service of manufacturing systems and products. The 4.0 designation signifies that this is the world's *fourth* industrial revolution, the successor to three earlier industrial revolutions (see Table 1) that caused quantum leaps in productivity and changed the lives of people throughout the world. In the words of German Chancellor Angela Merkel, Industry 4.0 is 'the comprehensive transformation of the whole sphere of industrial production through the merging of digital technology and the internet with conventional industry'. In short, everything in and around a manufacturing operation (suppliers, the plant, distributors, even the product itself) is digitally connected, providing a highly integrated value chain. The term *Industry 4.0* originated in Germany, but the concept largely overlaps developments that, in other European countries, may variously be labelled: *Smart factories*, *the Industrial Internet of Things*, *Smart industry*, or *Advanced manufacturing*.[3]

Industry 4.0 depends on a number of new and innovative technological developments:

- The application of **information and communication technology (ICT)** to digitise information and integrate systems at all stages of product creation and use (including logistics and supply), both inside companies and across company boundaries;

- **Cyber-physical systems** that use ICTs to monitor and control physical processes and systems. These may involve embedded **sensors**, intelligent **robots** that can configure themselves to suit the immediate product to be created, or **additive manufacturing** (3D printing) devices;
- **Network communications** including wireless and internet technologies that serve to link machines, work products, systems and people, both within the manufacturing plant, and with suppliers and distributors;
- **Simulation**, modelling and virtualisation in the design of products and the establishment of manufacturing processes;
- Collection of vast quantities of **data**, and their analysis and exploitation, either immediately on the factory floor, or through **big data** analysis and **cloud computing**;
- Greater ICT-based support for human workers, including robots, **augmented reality** and **intelligent tools**.

Industry 4.0 is expected to have a major effect on global economies. Industry 4.0 can deliver estimated annual efficiency gains in manufacturing of between 6% and 8%. The Boston Consulting Group predicts that in Germany alone, Industry 4.0 will contribute 1% per year to GDP over ten years, creating up to 390 000 jobs. Globally, one expert estimates that investment on the Industrial Internet will grow from US$20 billion in 2012 to more than US$500 billion in 2020 (albeit with slower growth after that date), and that value added will surge from $US23 billion in 2012 to US$1.3 trillion in 2020.

Table 1 – Industrial revolutions

	Time periods	Technologies and capabilities
First	1784-mid 19th century	Water- and steam-powered mechanical manufacturing
Second	Late 19th century -1970s	Electric-powered mass production based on the division of labour (assembly line)
Third	1970s-Today	Electronics and information technology drives new levels of automation of complex tasks
Fourth	Today-	Sensor technology, interconnectivity and data analysis allow mass customisation, integration of value chains and greater efficiency

Unsurprisingly, Europe is not the only region of the world to take an interest in digital manufacturing. The United States has established a National Network for Manufacturing Innovation with a proposed US$1 billion of public funding to bring together national research centres investigating topics such as digital manufacturing and design. Companies in the Asia/Pacific region were expected to invest almost US$10 billion in the Industrial Internet of Things in 2012, with that figure rising to nearly US$60 billion by 2020. If the EU is to remain competitive and to reach its goal of becoming a smart, sustainable and inclusive economy by 2020, European industry will need to capture the potential for productivity and growth that Industry 4.0 appears to offer.

What will Industry 4.0 change?

Digitalised manufacturing will result in a wide range of changes to manufacturing processes, outcomes and business models.

Smart factories allow **increased flexibility** in production. Automation of the production process, the transmission of data about a product as it passes through the manufacturing chain, and the use of configurable robots means that a variety of different products can be produced in the same production facility. This **mass customisation** will allow the production of small lots (even as small as single unique items) due to the ability to rapidly configure machines to adapt to customer-supplied specifications and additive manufacturing. This flexibility also encourages innovation, since prototypes or new products can be produced quickly without complicated re-tooling or the setup of new production lines.

The **speed** with which a product can be produced will also improve. Digital designs and the virtual modelling of manufacturing process can reduce the time between the design of a product and its delivery. Data-driven supply chains can speed up the manufacturing process by an estimated 120% in terms of time needed to deliver orders and by 70% in time to get products to market.

Integrating product development with digital and physical production has been associated with large improvements in **product quality** and significantly reduced error rates (see box). Data from sensors can be used to monitor every piece produced rather than using sampling to detect errors, and error-correcting machinery can adjust production processes in real time. This data can also be collected and analysed using 'big data' techniques to identify and solve small but ongoing problems. The rise in quality plays an important role in reducing costs and hence increasing competitiveness: the top 100 European manufacturers could save an estimated €160 billion in the costs of scrapping or reworking defective products if they could eliminate all defects.

Siemens electronic works, Amberg

The Siemens electronics plant in Amberg (Germany) produces custom Programmable Logic Controls (PLCs) in a state-of-the-art 'smart factory' where product management, manufacturing and automation systems are integrated. Intelligent machines coordinate the production and distribution of 950 products with more than 50,000 different variants, for which roughly 10,000 materials are sourced from 250 suppliers. By linking intelligent machines with data-rich components and workers, innovation cycles can be shortened, productivity raised and quality improved: the Amberg plant now records only 12 defects per million (versus 500 in 1989) and has a 99% reliability rate.

Productivity can also increase through various Industry 4.0 effects. By using advanced analytics in predictive maintenance programmes, manufacturing companies can avoid machine failures on the factory floor and cut downtime by an estimated 50% and increase production by 20%. Some companies will be able to set up 'lights out' factories where automated robots continue production without light or heat after staff has gone home. Human workers can be used more effectively, for those tasks for which they are really essential. For example, in the Netherlands, Philips produces electric razors in a 'dark factory' with 128 robots and just nine workers, who provide quality assurance.

Customers will be able to be more involved in the design process, even supplying their own modified designs which can then be quickly and cheaply produced. The **location** of some manufacturing operations may also be close to the customer: if manufacturing is largely automated, it does not need to be 'off-shored' or located in distant countries with low labour (but high transport) costs. European companies may decide to bring some manufacturing capacity back to Europe ('re-shore'), or to establish new plants in Europe rather than abroad.

Industry 4.0 will also provoke changes in **business models**. Rather than exclusively competing on cost, European companies can compete on the basis of innovation (the ability to deliver a new product rapidly), on the ability to produce customer-driven customised designs (through configurable factories), or on quality (the reduction of faults due to automation and control). Some companies may take advantage of the data created as 'smart' products are created and used, and adopt business models based on selling services not products (sometimes described as 'selling light not light bulbs'). This 'servitisation' can help to expand business opportunities and increase revenues.[4]

Challenges for Industry 4.0

Not every observer is convinced of the value that Industry 4.0 will add. Some feel that Industry 4.0 as a concept is poorly defined and suffers from exaggerated expectations; others believe that fully digitised products and value chains are still a 'pipe dream'. The Gartner Group's hype cycle for emerging technologies for 2014 places many of the technologies associated with Industry 4.0 (including machine-to-machine communications, big data, the Internet of Things and smart robots) near the 'peak of inflated expectations', still five to ten years from the point where the payoff for applying these in the broad market is evident. In a global 2013-14 survey, 88% of the respondents said they did not fully understand the underlying business models of the Industrial Internet of Things and its long-term implications for their industry. Even those convinced of the value of Industry 4.0 can foresee a series of barriers ahead.

Mass customisation

In a demonstration of mass customisation at the Hanover Fair in April 2015, one German company allowed participants to add names and symbols to an electric light switch. Order data about customisation in the form of a DM/QR code was passed through the production chain (including an injection machine and a 3D printer). In addition, the code was printed on the product box, where, by scanning it with a smartphone, the participant could access all the production data for their specific switch.

Online shoppers can also customise the design of their furniture when they buy from a Polish start-up which makes flat-pack furniture. A 'parametric modelling' app on a smartphone allows them to change the dimensions, configuration, wood and colour of a shelving unit, and visualise the result before their order is transmitted to factory machines. The unit is delivered with a unit-specific assembly manual. The company won the 'best use of technology' prize at a start-up festival in San Francisco in 2014.

Investment and change

Building a complex value network that can produce and distribute products in a flexible fashion means business leaders must accept to change and partner with other companies – not only suppliers and distributors of a product, but technology companies and infrastructure suppliers such as telecoms and internet service providers. Companies may even need to cooperate with competitors, e.g. in the establishment and use of standards that allow the transmission and exploitation of large quantities of data.

Large investments are needed if enterprises are to make the move to Industry 4.0; these are projected to be €40 billion annually until 2020 for Germany alone (perhaps as much as €140 billion annually in Europe). These investments can be particularly daunting for small and medium-sized enterprises (SMEs) who fear the transition to digital because they cannot access how it will affect their value chains. So far take up has been cautious: even in Germany (a leader in manufacturing), only an estimated one in five companies uses interconnected IT systems to control its production processes, though almost half intend to do so. Some critics say that systems are too expensive, too unreliable and oversized, and that the Industry 4.0 approach is being driven largely by equipment producers rather than customer demand.

Data ownership and security

With the large quantities of data being collected and shared with partners in the value network, businesses need to be clear about who owns what industrial data and to be confident that the data they produce will not be used by competitors or collaborators in ways that they do not approve. In particular, smart services will be based on the data generated by smart devices during their manufacture and use. For example, car-makers are reluctant to share data generated by their cars, for fear of finding their profits being squeezed by digital competitors. A single set of European rules on privacy, data storage and copyright, that balances trust and data protection, is considered by some to be a necessary step to ensuring European competitiveness.

Legal issues

Advanced manufacturing also raises a variety of legal questions including employee supervision, product liability and intellectual property. For example, data from a 'smart glove' that guides and records the movements of workers might be used to monitor or evaluate employees. If an autonomous manufacturing system that links different value networks produces a defective or dangerous product, how should the courts determine who in the network is responsible? If a customer requests an individualised product, who owns the intellectual property (IP) rights to the design? The French *Conseil d'analyse économique* has called for a balance between the stimulation of innovation by protecting IP and the sharing of knowledge, both sources of future progress.

Humans and machines

In the factory of the future, humans and machines can work closely together. Currently in an Airbus airplane factory, operators must follow tens of thousands of steps, with resulting high costs if one is missed or goes wrong. The current process involves more than a thousand different tightening tools. However Airbus is launching the development of network-enabled handheld tightening tools. For a particular task, employees can be quickly directed to the right tool which automatically 'knows' the next step and sets the correct calibration for the specific part that the employee wants to tighten. The smart tools can also record the operation to ensure quality control and eliminate manual logging.

Standards

Standards are essential to ensure the exchange of data between machines, systems and software within a networked value chain, as a product moves into and through the 'smart factory' towards completion, as well as to allow robots to be integrated into a manufacturing process through simple 'plug-and-play' techniques.[5] If data and communication protocols are proprietary or only recognised nationally, only the equipment of one company or group of companies will be compatible; competition and trade can be expected to suffer and costs rise. On the other hand, independent, commonly agreed, international standard communication protocols, data formats and interfaces can ensure interoperability across different sectors and different countries, encourage the wide adoption of Industry 4.0 technologies, and ensure open markets worldwide for European manufacturers and products. A foresight study by the Joint Research Centre emphasised the need for anticipating standards requirements and accelerating their development in Europe.

Employment and skills development

The nature of manufacturing work has been shifting from largely manual labour to programming and control of high performance machines. Employees with low skill levels risk becoming replaceable unless they are retrained. On the other hand, workers able to make the transition to Industry 4.0 may find greater autonomy and more interesting or less arduous work. Employers need personnel with creativity and decision-making skills as well as technical and ICT expertise. By 2020, labour markets in the EU could be short of as much as 825 000 ICT professionals; this shortage may be even more pronounced in advanced manufacturing settings where big data analysts and cybersecurity experts are required. While various initiatives have been undertaken to encourage the acquisition of 'eSkills', young people may not necessarily be interested by the digitalisation of the workplace: in one survey only 13% of young adults in Germany would definitely consider a career in ICT despite the majority view that the sector offered the best job prospects.

EU policy

Policies to support Industry 4.0 developments

In the 2014 Communication 'For a European Industrial Renaissance', the European Commission stated that digital technologies (including cloud computing, big data, new industrial internet applications, smart factories, robotics and 3D printing) are essential to increase European productivity through redefining business models and creating new products and services. In its 2012 industrial policy Communication, the Commission identified six priorities, three of which cover areas directly related to Industry 4.0, namely advanced manufacturing, key enabling technologies (e.g. batteries, intelligent materials and high performance production processes), and smart grids and digital infrastructures (where infrastructure and connectivity for the industrial internet is considered to be of key importance). This earlier Communication also set the target of increasing the manufacturing share of total value added in the EU to 20% by 2020. Nevertheless, some observers have characterised this goal as unachievable in the foreseeable future because of overcapacity and weak economic growth as well as the greater growth potential in the services sector (and hence rising proportion of services in total value added).

Areas for policy interventions

A 2014 survey of business leaders in Germany highlighted areas where they believed support from policy-makers was needed for Industry 4.0. The top concerns were the education and training of qualified personnel (mentioned by 32% of respondents as being one of the top two issues), support for international standardisation (30%), competitive laws on data protection (28%) and tax incentives for corporate investments (27%).

A smaller number of global leaders, asked a similar question concerning the top *three* public policy actions for the Industrial Internet of Things, identified as most important the provision of regulatory frameworks (67%), education and training (55%), long-term strategic R&D (48%), and establishment of common standards (47%).

In 2013, the Commission created a Task Force on Advanced Manufacturing for Clean Production and, in 2014, a Strategic Policy Forum on Digital Entrepreneurship to focus on the digital transformation of European industry and enterprises. The latter group recommended setting national targets, establishing centres of excellence, reinforcing standardisation, providing funding and boosting digital skills development. It also called for establishment of an observatory for digital transformation and increased political awareness of digital issues and policy effects. The EU has also promoted eSkills to reduce shortages of workers with ICT skills, most notably by creating a multi-stakeholder partnership called the Grand Coalition for Digital Jobs to make ICT education more attractive and better aligned to industry needs. The European Council has also called for greater digital and data-driven innovation in all sectors of the economy, as well as the use of funding from the European Structural and Investment Funds (ESIF) to support ICT education and vocational training. The Commission's Digital Single Market Strategy promises to address data ownership and interoperability in business-to-business and machine-to-machine communications in a 2016 'Free flow of data' initiative, as well as encouraging standards for digitisation in the industrial sector and developing digital skills and expertise.

Position of the European Parliament

In a 2012 own initiative resolution, the European Parliament expressed the view that the EU should support SMEs especially in relation to high value-added and technologically advanced manufacturing. In another 2014 own initiative resolution on reindustrialising Europe (in response to the Commission's 2012 updated communication on industrial policy), Parliament underlined the potential of advanced manufacturing to regenerate the EU's industrial base. Parliament called for the creation of a Knowledge and Innovation Community (KIC) for advanced manufacturing[6] and for greater synergies between initiatives in this field in Member States, research institutes and industry.

Funding for Industry 4.0-related initiatives

As part of its promotion of the digital economy, the EU supported an action from 2008 to 2014 that focused on the smart use of ICT and the integration of SMEs into digital value chains, with a particular focus on global markets. From 2014-20, the **Horizon 2020** research programme's industrial leadership pillar will provide almost €80 billion for research and innovation, including support for developing key enabling technologies. The research programme will also finance prototypes and demonstration projects. Factories of the Future is a public-private partnership (PPP), launched initially under the earlier Seventh Framework Programme but continuing under Horizon 2020, that centres on advanced, smart, digital, collaborative, human-centred and customer-focused manufacturing (indicative budget €1.5 billion). Another PPP, Sustainable process industry through resource efficiency (SPIRE) has a budget of €0.9 billion. Still ongoing is the Seventh Framework initiative ICT Innovation for Manufacturing SMEs (I4MS) which aimed to help SMEs and mid-cap manufacturing companies master the digital transformation in areas such as cloud computing, robotics and simulation (€77 million). In addition, at least €100 billion from the **European Structural and Investment Funds (ESIF)** are available to Member States to make investments in innovation, in line with the concept of 'smart specialisation' which encourages regions to concentrate on their comparative advantages and to create pan-European value changes.

Member States

A number of EU Member States sponsor Industry 4.0-related initiatives, including Germany, Italy, France and the UK, which represent the largest industrial sectors by value added in the EU. Starting in 2010, the **German** government has contributed €200 million to the *Industrie 4.0* initiative (one of ten projects within the German High Tech Strategy 2020 Action Plan), to encourage the development of 'smart factories'. Building on Germany's strength in embedded systems, this initiative brings together private businesses, the public sector and academia to create and implement a 10 to 15-year plan for applying digital technologies to the industrial sector.

In **Italy**, the Fabbrica del Futuro project (2011-13) supported research initiatives in areas including customisation of products, reconfigurable factories, high performance and sustainability. By making use of technologies in the areas of ICT, material recovery, control systems, factory reconfiguration, quality control and man-machine interaction, the project aimed to enhance quality, flexibility and customisation in manufacturing.

The **UK** has initiated a number of policies to make manufacturing more responsive, more sustainable, more open to new markets and more dependent on skilled workers.

Best known are the high-value manufacturing centres, called 'Catapult centres', that help companies to access research and expertise in specialised areas such as advanced manufacturing and process innovation. The aim of these centres, which have received more than £200 million of government funding since 2011, is to double the contribution of manufacturing to GDP (about 10% in previous decades). In addition, in 2012, the government provided £170 million in funds to established or new suppliers through an Advanced Manufacturing Supply Chain Initiative fund; and £50 million to continue the Manufacturing Advisory Service (founded in 2002) from 2011-12 to 2013-14, recently with a particular emphasis on SMEs.

In April 2015, **France** launched a plan for the Factory of the Future to create demonstration centres (*vitrines technologiques*) to showcase new products and services. Particular emphasis has been placed on aid to small and medium-sized enterprises, with €1 billion available in loans to SMEs that want to start robotics, digitalisation or energy-efficiency projects. This new plan, and six others in the same industrial support programme (dealing with robotics, the Internet of Things, Big Data, high performance computing, Cloud Computing and augmented reality), have been grouped together in a larger framework called 'Industry of the future', that focuses on specific products such as an energy-efficient car and an electric airplane.

Stakeholder positions

In its assessment of the European Commission's 2015 Digital Single Market Strategy, the European Trade Union Confederation (ETUC) emphasised the huge impact of Industry 4.0 on employment and work, with the risks of new monopolies, mass redundancies, spying on workers, and the extension of precarious digital work. While supporting initiatives to upgrade skills and recognising the potentially emancipatory effects of automation, ETUC believes that Industry 4.0 requires a new social contract, with improved worker consultation and participation. IndustrialAll, a European trade union of manufacturing workers, has highlighted the role of open standards for digital manufacturing in ensuring quality jobs in Europe. Representing European engineering industries, Orgalime prefers transposing international standards for use in Europe rather than ensuring global relevance for European-developed standards. BusinessEurope has underlined the fact that there is no coherent pan-European development of Industry 4.0, but sees digitalised manufacturing as a boost to the reindustrialisation of Europe through faster development and production, greater manufacturing flexibility and increased resource efficiency. DigitalEurope, representing the European ICT industry, has underlined the importance of international agreements in the transition towards Industry 4.0 and the inclusion of European industry in global value chains.

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Endnotes

[1] However, considerable differences exist between the proportional value added of manufacturing in different Member States, with some preserving their industrial rate over the past ten years (e.g. Germany, Italy) while others have seen substantial falls (e.g. France, Spain, the UK).

[2] A part of this shift is due to the outsourcing of industry activities, such as logistics, to specialised companies that are counted as part of the services, not industrial, sector.

[3] Advanced manufacturing is a somewhat broader term that may also be used to refer to manufacturing techniques for new materials such as plastic electronics and composites.

[4] Servitisation refers to the trend that manufacturing firms sell ongoing services to their customers (alongside or instead of products) based on a holistic view of customer needs. For example, airplane engine manufacturer Rolls Royce offers to sell clients 'guaranteed flight hours' rather than just selling them engines as a physical product. Servitisation provides an opportunity to increase revenue streams and to differentiate an offer from products produced in lower cost economies.

[5] Different consortia of companies (e.g. the Industrial Internet Consortium, the AllSeen Alliance and the Open Interconnect Consortium) are already working on standards, but their work is not necessarily compatible.

[6] The Commission plans to launch a KIC for advanced manufacturing in 2016.

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