European Parliament

DIRECTORATE-GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT A
ECONOMIC AND SCIENTIFIC POLICY

Economic and Monetary Affairs

Employment and Social Affairs

Environment, Public Health and Food Safety

Industry, Research and Energy

Internal Market and Consumer Protection

Industry 4.0

Study for the ITRE Committee

EN

2016

Industry 4.0

European Parliament

DIRECTORATE GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT A: ECONOMIC AND SCIENTIFIC POLICY

Industry 4.0

STUDY

Abstract

This study, prepared by Policy Department A at the request of the ITRE committee, analyses the Industry 4.0 Initiative which encompasses the digitalisation of production processes based on devices autonomously communicating with each other along the value chain. It considers the potential of the initiative and business paradigm changes and impacts of this transformation. The study assesses the rationale for public intervention and outlines measures that could be adopted to increase the gains and limit the threats from Industry 4.0.

IP/A/ITRE/2015-02 February 2016

PE 570.007 EN

This document was requested by the European Parliament's Committee on Industry, Research and Energy (ITRE)

AUTHOR(S)

Jan SMIT, Centre for Strategy & Evaluation Services LLP
Stephan KREUTZER, Centre for Strategy & Evaluation Services LLP
Carolin MOELLER, Centre for Strategy & Evaluation Services LLP
Malin CARLBERG, Centre for Strategy & Evaluation Services LLP

RESPONSIBLE ADMINISTRATOR

Frédéric GOUARDÈRES

EDITORIAL ASSISTANT

Mirari URIARTE

LINGUISTIC VERSIONS

Original: EN

ABOUT THE EDITOR

Policy departments provide in-house and external expertise to support EP committees and other parliamentary bodies in shaping legislation and exercising democratic scrutiny over EU internal policies.

To contact Policy Department A or to subscribe to its newsletter please write to:
Policy Department A: Economic and Scientific Policy
European Parliament
B-1047 Brussels
E-mail: Poldep-Economy-Science@ep.europa.eu

Manuscript completed in February 2016

This document is available on the Internet at:
http://www.europarl.europa.eu/studies

DISCLAIMER

CONTENTS

LIST OF ABBREVIATIONS

CP(P)S	Cyber physical (production) sysems
EFFRA	European Factories of the Future Research Association (EFFRA)
FET	Future and Emerging Technologies Programme
ICT	Information and Communication Technologies
II	Industrial Internet
IoT	Internet of Things
RFID	Radio Frequency identification
STEM	Science, technology, engineering, mathematics

LIST OF TABLES

LIST OF CHARTS

LIST OF FIGURES

EXECUTIVE SUMMARY

This report presents the findings of an analytical study on 'Industry 4.0' carried out by CSES for the European Parliament. The study aims to inform the debate about the role of industrial policy at an EU level in supporting Member States (MS) and enterprises as regards the transformation required to connect digital technologies with industrial products and services.

The study first sets out the current industrial policy debate and its evolution. Then it looks into the details of Industry 4.0. Next three key dimensions of change relevant to Industry 4.0 are explored: technological, social and the business paradigm. Finally the policy implications are outlined and recommendations are made.

Industry 4.0 describes the *organisation of production processes based on technology and devices autonomously communicating with each other along the value chain:* a model of the 'smart' factory of the future where computer-driven systems monitor physical processes, create a virtual copy of the physical world and make decentralised decisions based on self-organisation mechanisms. The concept takes account of the increased digitalisation of manufacturing industries where physical objects are seamlessly integrated into the information network, allowing for decentralised production and real-time adaptation in the future.

Industry 4.0 was initially developed by the German government to create a coherent policy framework to maintain Germany's industrial competitiveness. Related terms used internationally include *Internet of Things*, *Internet of Services*, *Industrial Internet*, *Advanced Manufacturing* and *Smart Factory*.

Industry 4.0 will only succeed if certain key requirements are met: standardisation of systems, platforms, protocols; changes in work organisation reflecting new business models; digital security and protection of know-how; availability of appropriately skilled workers; research and investment; and, a common EU legal framework to support the dissemination of Industry 4.0 in the Internal Market. If successfully implemented, the potential benefits of Industry 4.0 relate to productivity gains, revenue growth, and competitiveness. The implementation horizon is to have pilots running in 2016 and full implementation as of about 2025.

The policy approach in support of Industry 4.0 is to develop new **lead markets** in a **dual strategy** where a) Industry 4.0 technology and services could be sold and b) where manufacturing and other products more generally can be sold more easily thanks to productivity and competitiveness gains. A key in succeeding with this strategy will be to integrate SMEs, who often operate on a regional basis, into global value chains.

The study considers **three dimensions of change** that are of relevance in relation to Industry 4.0: technological change, social change and change in the business paradigm. As regards **technological** change, digitalisation has been a major driver of changes throughout the value chain, and while many businesses recognise the need to adjust, far fewer, especially among SMEs, are prepared for it. There are significant challenges (costs and risks) for firms as regards digital security in: intellectual property protection, personal data and privacy; design and operability of systems; environmental protection and health and safety. Public institutions have been created in many countries to improve cybersecurity. There is wide-ranging support for research at both EU and Member State level, but a good deal remains to be done.

In the field of **social change** there is little awareness of Industry 4.0 outside the group of key stakeholders. Larger firms tend to be more positively disposed whereas unions remain cautious and have reservations. While a skills gap (as well as a gap in willingness) to adjust to the Digital Single Market exists, the skill requirements to adjust to Industry 4.0 are much greater. New ways of work are needed, which have positive and negative impacts on employees; and the gap in domestic (and EU) supplies of skills is currently being addressed through sophisticated immigration strategies. The supply of Industry 4.0 skills and capabilities throughout the EU is uneven, which is likely to lead to increased concentration in and competition between existing centres.

Change in the business paradigm: there are challenges for SMEs in participating in Industry 4.0 supply chains (costs, risks, reduced flexibility and reduced strategic independence). The public rector can play a role in creating an ecosystem that will help SMEs transition to Industry 4.0, but little research has been carried out in this area. Standardisation remains a major challenge as regards large scale implementation of Industry 4.0. The question as to whether Industry 4.0 will strengthen the EU industry's leadership, or if it is more of a necessary requirement to maintain its position, or if leadership will inevitably pass to the new emerging economies such as China through the international diffusion of technology by multinational enterprises, remains to be answered.

An **intervention from the public sector** could take various forms, but the one most promising appears to be to support research at EU and Member State levels and to coordinate initiatives across the EU, e.g. through a platform and to illustrate good practices of initiatives in some MS that others could follow. In order to maximise added value, initiatives should go beyond merely technical aspects and the manufacturing sector, and should reflect the differences in Member States' economic structures. Direct intervention in markets appears to be less promising.

In summary, the study **recommends**:

- A review of ***existing measures*** targeting Industry 4.0 (and related initiatives) to ensure that they consider the most important aspects – e.g. skills, migration, business model change, clusters, cross-border collaboration programmes for enterprises, cybersecurity and standards, and implications for SMEs and European competitiveness.
- Adopting ***new measures*** where gaps are identified at EU and Member State level to monitor latest developments, fund research and support SMEs, raise awareness of challenges and opportunities, support development of a framework including standards and play a coordinating role.

1. INTRODUCTION – AIMS OF THE STUDY

This document presents an *analytical study* on 'Industry 4.0' for the European Parliament's Committee on Industry, Research and Energy (ITRE) prepared by the Centre for Strategy and Evaluation Services LLP (CSES). In this introductory section is set out the aims and scope of the study, the methodology adopted and the structure of the report.

1.1 Aims

The purpose of the study is to inform the debate about the role of a coordinated and integrated industrial policy at an EU level in supporting the economies of the Member States and contributing to the competitiveness of European enterprises, including SMEs, and in particular as regards connecting digital technologies with industrial products and services. The study aims to enable Members of the ITRE Committee to establish their own view of Industry 4.0, and on whether policies have been effectively implemented and to what extent.

The study also aims to pay close attention to analysis of how national and EU policies are capable of speeding up the rate of industrial transformation to high-added-value added products, processes and services, securing highly skilled employment and winning a major share of world manufacturing output.

In particular, the study aims to show how and to what extent proposed measures to support Industry 4.0 are implemented at community level, and identify bottlenecks that will affect their development.

The overall aim is to provide a balanced presentation of the variety of views seriously considered among professionals in this field as well our own independent assessment.

1.2 Scope of the Study

The scope of the study is to analyse how the concept of Industry 4.0 is implemented and to describe the necessary measures to create and serve new lead markets for technologies and products. The study addresses, among others, the following issues:

Table 1.1: Industry 4.0 – issues addressed

Technological change	Societal change	Business paradigm change
Will "Industry 4.0" *announce* a technological change with some implications on *social*, *juridical* and *political* issues? While an increase in *digital security* becomes predominant, what are the *risks* associated with Industry 4.0? To which extent does/ will Industry 4.0 produce breakthrough technologies and is it actively involved in cross-fertilisation with other sectors? What are the key measures to support	What is the *public awareness and acceptance* of internet based products and services? Will there be a *shortage of skills*? How to *facilitate mobility* between Member States and between the public and private sectors?	How *sustainable* is Industry 4.0? What could be the *footprint* of Industrial Internet? What are the *obstacles to the participation of* SMEs in the supply chain of the manufacturing industry? Is the *lack of standardisation* an issue? What are the limitations to the export of Industry 4.0 equipment and services? Describe the different measures in place to further develop a competitive industrial base in Europe and support SME participation. Will "Industry 4.0" allow the EU to

Technological change	Societal change	Business paradigm change
research and innovation in the manufacturing sector at national and EU level? What is the state of play of research and development in this area? What could emerge rapidly?		increase its global competitiveness and preserve its domestic manufacturing industry?

The main focus of the research is on how Industry 4.0 has emerged in Germany as this is where it originated and where most of the relevant development and implementation of the initiative has been carried out. However, developments in other Member States are also mentioned.

Policy Recommendations

In order to improve legal coherence and facilitate implementation, the study aims to elaborate some policy recommendations relative to the findings. Based on the analysis of the benefits and drawbacks, the study provides two kinds of recommendations:

- Whether some new policies should be envisaged and for which domain of applicability.
- Whether there is a need for an improved and /or refined implementation of existing actions.

1.3 Methodological approach

This “analytical study” is based on relevant information already available on the subject and analysis of relevant statistical data. As the terms of reference point out, this means that there are certain limitations in such an approach. In particular, this means that views, opinions or arguments exist that have not yet been put forward in the form of codified knowledge will not be included in the feedback.

1.4 Structure of the report

After this introductory section, section 2 summarises the development of and key issues in the industrial policy debate in the EU. Section 3 sets out what is meant by the term “Industry 4.0”, and section 4 considers how the idea of lead markets applies to Industry 4.0. Section 5 goes into some detail in considering what the technological, social and business implications of Industry 4.0 are. Section 6 looks at current policies: what is being done, are there any gaps, what can be done; and section 7 assesses Industry 4.0. In the final section, 8, recommendations are made.

There are four Annexes (A-D): one dealing with Industry 4.0 research questions; one with the four case studies ; one with a map of EU Initiatives and the last one with some information about industrial, manufacturing and Industry 4.0-type initiatives in several Member States.

2. CURRENT INDUSTRIAL POLICY DEBATE IN THE EU

KEY FINDINGS

- There have been two phases in industrial policy in Europe since 1945: one of selective targeted strategies until the 1970's, followed by an approach aimed at creating a favourable operating environment.
- EU industrial policy since 2000 has been driven by the Lisbon Agenda and then Europe 2020 (since 2010). Currently policy is aimed at generating an "Industrial Renaissance" in Europe.
- Several issues need to be considered in the context of assessing a policy initiative such as Industry 4.0, and relevant data on industrial performance for key European economies such as the UK, France, Italy and Spain also need to be borne in mind.

2.1 Overview of the development of industrial policy and the policy debate

Industrial policy in Europe between 1945 and the crisis of 2008 can be characterised as having gone through two phases.[1] The first phase, lasting until about 1980, saw national governments adopting selective targeted strategies to create leading industries ("national champions") to drive development in the national economy. Often these were "high-tech" sectors selected to bridge the "technology gap" – a productivity gap – between Europe and the USA. Economies of scale were also seen as a major driver of international competitiveness. Generally speaking, such interventions tended to be unsuccessful while de-industrialisation to the Newly Industrialised Countries (NICs) continued.[2]

The second phase featured more "horizontal" approaches aimed at improving the operating environment for all firms, both at national and European level and creating an enabling environment where firms can be competitive.[3] Direct support (and protection) of industry was curtailed and institutions established to promote intra-European co-operation in research. But the surge in US productivity during the1990's suggested that another model could be followed - that of supporting the growth of entrepreneurial high-tech firms, supported by a strong venture capital industry and stock market accessible to younger firms. In addition, the large scale liberalisation of the world economy ("globalisation") since the early 1990's created many new opportunities and threats for industry in the advanced industrial economies. By the early 2000's, industrial policies were again in a state of flux in an attempt to increase productivity and competitiveness in the context of new global realities. When the crisis of 2008-09 struck it acted as a catalyst for new thinking.

2.2 Developments at European level

Initial, embryonic, steps towards an EU-level industrial policy were taken with the Prest (Politique de Recherche Scientifique et Technologique) committee during the 1960's, followed by the COST (European Co-operation in the field of Scientific and Technical Research) framework in the early 1970's.[4] During the1980s two initiatives at EU level aimed at improving industrial performance were launched: ESPRIT (European Strategic

---

1 Owen, G. (2012); Industrial Policy in Europe since the Second World War: What Has Been Learnt?, ECIPE Occasional Paper, 1/ 2012, p.2

2 See for example Beenstock, M. (1983); The World Economy in Transition, George Allen & Unwin; and, Harris, N. (1986:; The End of the Third World, Penguin

3 See for example a key text of the period: Porter, M. (1993); The Competitive Advantage of Nations,

4 Owen, op.cit., p.20

Programme for Research in Information Technologies) and the Single Market Programme (SMP). Other collaborative programmes followed (e.g. RACE, BRITE). They were subsequently packaged into the First Framework Programme. EUREKA (European Research Co-ordination Agency) was proposed in 1985. The Single European Act of 1986 was aimed at removing non-tariff barriers to increase competition and the size of the market.

EU industrial policy was first given a title and legal basis in the 1992 Maastricht Treaty[5]. Policy at the time was geared towards the creation of more dynamic industrial sectors.[6] [7] During the 1990s, the policy priorities of the EU largely focused on the Internal Market and the creation of a monetary union. This period was also characterised by a decline of the share of industry and an increase in the service sectors in the economy, and the emergence of the 'knowledge' economy. As a result, industry lost some of its priority as part of European economic policy. This ended in the early 2000s when the impact of globalisation became more evident and when, with a more advanced Internal Market and monetary union – the EU was again expanding.

The aim of the *Lisbon agenda* adopted in 2000 was to make the European Union "the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion."[8] The Lisbon agenda involved interventions to boost investment in R&D, completing the single market, especially in services (structural reforms), and increasing labour market flexibility and participation rates. However, the programme was dependent on implementation by national governments and after reviews by Andre Sapir and Wim Kok the agenda was relaunched in 2005. Between 2002 and 2005 the Commission published a yearly communication on industrial policy. The Parliament also supported development of a robust industrial policy and has passed a series of resolutions on issues of major concern in the area.[9]

The basis for the current developments is found in Article 173 of the Lisbon Treaty (TFEU), which governs industrial policy. The Article does not provide for dedicated policy instruments but intends that industrial policy should be pursued through policies and activities under other provisions of the Treaty[10]. EU industrial policy is consequently focused on the adjustment of industry to structural changes, encouraging cooperation between undertakings, and fostering the industrial potential of innovation, research and technological development, plus a number of peripheral policies which also interplay with industry policy; either through the use of regulatory instruments or through budgetary instruments.[11] One such a policy was the Lead Markets Initiative, aiming to support

---

5 The EP has a long tradition of supporting a EU industrial policy. Already in 1981, the Parliament pressured the Commission to finish and publish a new Communication to re-launch the industrial policy. This attempted to compare the EU's overall industrial performance with its main trading partners and suggested turning the internal market into "a genuine European industrial continuum, but with an element of Community priority in cases where industrial development involves the participation of the public authorities". Source: Y Sun, *Industrial Policy of the EU: Development and Recent Progress*, Working Paper Series on European Studies, Institute of European Studies, Chinese Academy of Social Sciences, Vol. 1, No. 8, 2007

6 General principles of EU industrial policy – see: http://www.europarl.europa.eu/aboutparliament/en/displayFtu.html?ftuId=FTU_5.9.1.html

7 Y Sun, *Industrial Policy of the EU: Development and Recent Progress*, Working Paper Series on European Studies, Institute of European Studies, Chinese Academy of Social Sciences, Vol. 1, No. 8, 2007

8 Owen, op.cit., p.39

9 E.g. Resolution of 13 June 2002 assessed the Commission Communication of November 2001 "Sustaining the commitments, increasing the pace" (COM (2001) 641); Resolution of 9 March 2011 on an Industrial Policy for the Globalised Era; Resolution of 26 October 2011 on the Agenda for New Skills and Jobs; Resolution of 15 January 2014' Reindustrialising Europe to promote competitiveness and sustainability'

10 Y Sun, *Industrial Policy of the EU: Development and Recent Progress*, Working Paper Series on European Studies, Institute of European Studies, Chinese Academy of Social Sciences, Vol. 1, No. 8, 2007

11 These include: liberalisation of the world trading system; Single market related policies; Energy and transport policies; R&D policy; Competition policy; Regional policy; Social and employment policies; Consumer protection and public health policy; and Environmental protection.

markets with high growth potential where European companies were well-placed to compete (see section 3).

2.3 After the crisis

The consequences of the financial crisis, together with the continued (renewed) lag in EU productivity behind that of the USA and the increasing share of manufacturing in the newly industrialising countries, especially China, also at the high-end of the value chain, acted as a catalyst for a review of industrial policy in the EU. However the crisis also sparked a worldwide renewed interest in industrial policy in many countries including China, Brazil, the USA, France, the UK the Netherlands, India, etc. While many of these policies were related to the decline of the share in manufacturing in their economies, others were concerned with how to deal with increases in the share and moving up the value chain.[12] The main drivers of renewed concern have been: the search for measures to stimulate growth and employment in response to the crisis; adjustment to structural change; the prevalence of market failures; the political economy of bail-outs; and, the emerging (market) economies.

In the EU, during the period after the crisis, and with the relaunch of Lisbon, several initiatives were aimed at encouraging industry to develop into new technological areas. Some were selective and costly (e.g. Galileo and Iter). But most have been horizontal in nature, aimed at improving the environment for entrepreneurial firms, collaborative research and individual programmes.

Under the Europe 2020 strategy industrial policy, a revised version of Lisbon, launched in 2010, became an increasingly important priority[13]. The Europe 2020 strategy includes seven Flagship Initiatives including an "integrated industrial policy for the globalisation era". The approach is primarily horizontal to influence the framework conditions for improving innovation and productivity. But it recognises that general policies affect different sectors in different ways – the "matrix approach" – which need to be taken into consideration, and that some sectors may need complimentary measures to influence competitiveness.[14]

In October 2012, the European Commission published its Communication "A Stronger European Industry for Growth and Economic Recovery" which recognised the relative deterioration of European industry and emphasised that "a strong industrial base is essential for a wealthy and economically successful Europe[15]". The Communication called for the Member States to endorse the Commission's four-tiered approach to industrial policy:

1. *Provision of suitable framework conditions to stimulate new investments, speed up the adoption of new technologies and boost resource efficiency,* encompassing technical regulations and Internal Market rules, policy measures supporting infrastructure and R&D/innovation projects. Six initial priority areas for immediate action were proposed: i) Markets for advanced manufacturing technologies for clean production, ii) Markets for key enabling technologies, iii) Bio-based product markets, iv) Sustainable industrial policy, construction and raw materials, Clean vehicles and vessels, vi) Smart grids.

---

[12] Warwick, K. (2014); Beyond Industrial Policy: Emerging Issues and New Trends, FIW Workshop, An Industrial Renaissance in Europe, Vienna, 6th June 204.

[13] Y Sun, *Industrial Policy of the EU: Development and Recent Progress*, Working Paper Series on European Studies, Institute of European Studies, Chinese Academy of Social Sciences, Vol. 1, No. 8, 2007

[14] Owen, op.cit., p.45

[15] Communication (EC) No. 582 final, *A Stronger European Industry for Growth and Economic Recovery Industrial Policy Communication Update*, 2012

2. *Urgent improvements in the functioning of the Internal Market* to contribute to reinvigorated trade in the Internal Market. *Liberalisation of international markets* (in particular to fast-growing emerging economies) to offer new export opportunities for EU firms especially SMEs.
3. *Adequate access to finance* to underpin investment and innovation (public and private).
4. *Increased investment in human capital and skills to* enable industrial transformation[16].

The Commission created task forces to deal with the six policy areas identified (see 1 above). The task force dealing with 'advanced manufacturing for clean production' seeks to support the modernisation of European manufacturing companies.[17] In February 2015, a workshop was held to identify SME readiness factors for adopting advanced manufacturing.

The European Parliament responded to the 2012 Communication by launching the strategy entitled 'A Renaissance of Industry for a Sustainable Europe (RISE)', which included a strategy for a RISE in the southern EU Member States[18] and adopted a resolution in January 2014 that *inter alia* emphasised that industrial policy is essential for economic development and competitiveness, ensuring long-term prosperity and solving the problem of unemployment. The interdisciplinary nature of industrial policy – and the need to act across policy areas – was underlined.[19]

The resolution also put forward a short-term agenda for RISE to meet the urgent challenges in some industry sectors as well as a longer-term roadmap providing "incentives for steering investments into creativity, skills, innovation, new technologies and promoting the modernisation, sustainability and competitiveness of Europe's industrial base through a value chain-conscious policy that covers undertakings of all sizes, pays due attention to the basic industries and is conducive to maintaining the production chain in Europe" [20]. The roadmap should support both key industries and new sectors of industry and must be geared towards growth in accordance with sustainable development principles[21].

Following the resolution, the Commission adopted the Communication 'For a European Industrial Renaissance'[22] as a contribution to the 2014 March European Council debate on industrial policy. It set out a vision of a third industrial revolution in Europe and called on Member States to recognise the central importance of industry for creating jobs and growth, and the need to mainstream industry-related competitiveness concerns across all policy areas. In particular, there needs to be support for the modernisation and sustainable re-growth of European industry under a revised 'competitive framework'. It proposed the priorities which reflected many of the points raised in the Parliament's RISE strategy, calling on Member States to endorse the reindustrialisation efforts in line with the

---

[16] Communication (EC) No. 582 final, *A Stronger European Industry for Growth and Economic Recovery Industrial Policy Communication Update*, 2012

[17] European Commission, *Advanced Manufacturing,* http://ec.europa.eu/growth/industry/innovation/advanced-manufacturing/index_en.htm

[18] See European Parliament 2013/2006(INI) - 18/12/2013 Committee report tabled for plenary, single reading, http://www.europarl.europa.eu/oeil/popups/summary.do?id=1329735&t=d&l=en and EurActiv, *Presentation of the EP's draft report on European industrial policy,* press release, http://pr.euractiv.com/pr/presentation-eps-draft-report-european-industrial-policy-97094

[19] European Parliament Resolution of 15 January 2014 on reindustrialising Europe to promote competitiveness and sustainability (2013/2006(INI)), http://www.europarl.europa.eu/sides/getDoc.do?type=TA&language=EN&reference=P7-TA-2014-0032

[20] European Parliament Resolution of 15 January 2014 on reindustrialising Europe to promote competitiveness and sustainability (2013/2006(INI)), http://www.europarl.europa.eu/sides/getDoc.do?type=TA&language=EN&reference=P7-TA-2014-0032

[21] European Parliament Resolution of 15 January 2014 on reindustrialising Europe to promote competitiveness and sustainability (2013/2006(INI)), http://www.europarl.europa.eu/sides/getDoc.do?type=TA&language=EN&reference=P7-TA-2014-0032

[22] Communication (EC) For a European Industrial Renaissance, COM/2014/014 final

Commission´s aspiration of raising the contribution of industry to GDP to as much as 20% by 2020[23]. The policy announcements were supported by a series of analytical documents[24] and studies[25] which highlighted the further fall in manufacturing's contribution to EU GDP (to 15.1 %). Recently, the report of the High Level Group on Business Services[26] addressed the consequences of manufacturing incorporating an increasing share of services into the offer that it makes to the market.

2.4 Issues underlying the policy debate

Underlying the development of this debate have been certain issues. The issues relate to the thrust of industrial strategy; the state of current practice; and some emerging lessons of recent years.

The *strategic thrust of policy* can be summarised as achieving a specific balance in terms of pro-active/ defensive-reactive as represented in the matrix below. Section 5 suggests that there are differences between the EU as a whole and individual member states as regards the perceived role that an initiative such as Industry 4.0 would have.

Chart 2.1: Two-way classification of industrial policy

	Comparative advantage developing		
Catch-up	Infant industry	Seeking strategic advantage in new areas	**Frontier**
	Building on strengths in development	Consolidating on frontier strengths	
	Comparative advantage-following		

Source: Warwick, op. cit.

The *general state of the debate* on industrial policy can be summarised as follows:[27]

- There is no "one size fits all" - approaches vary with the stage of development of the country and/or 'sector'.
- Some states are moving to more horizontal policy; while others are moving to more selective approaches.
- Both flexibility and tenacity are needed.
- There is some convergence in thinking on "fourth generation" industrial policy with emphasis on systems, networks, institutions and capabilities.
- The risks of "government failure", policy capture, and protectionism need to be identified and assessed.
- There are major challenges as regards evaluation, especially of strategy and policy programmes.

23 Communication (EC) For a European Industrial Renaissance, COM/2014/014 final
24 Staff Working Document (EC) State of the Industry, Sectoral overview and Implementation of the EU Industrial Policy, 2014/014 final
25 E.g. European Commission, *Member States' Competitiveness Performance and Implementation of EU Industrial Policy report*, SWD(2013) 346, 2013
26 European Commission, *Final Report of the High Level Group on Business Services*, April 2014
27 Warwick, op. cit.

According to Rodrik (2008)[28]: "The emerging consensus is that the risks associated with selective strategic industrial policy can be minimised through a 'soft' form of industrial policy, based on a more facilitative, coordinating role for government, consistent with the systems approach...The goal of 'soft' industrial policy is to develop ways for government and industry to work together to set strategic priorities, deal with coordination problems, allow for experimentation, avoid capture by vested interests and improve productivity."

Emerging lessons learnt from previous decades on implementation of policy are:

- Remove barriers before providing support - i.e. "don't push on a string"
- Ensure clarity in objective(s) – so that success and failure can be assessed in a non-discretionary manner
- Keep the "outsiders and the unborn" in mind – resist political economy pressures from insiders and incumbents
- Evaluate (preferably ex ante, interim and ex post) – and incorporate evaluation in policy cycle
- Ensure that the public bears a risk which is "proportionate" (enough to matter, not too much to lead to moral hazard)
- Plan for exit – and make the plan known

2.5 Key data

Manufacturing provides about 20% of all jobs in Europe (more than 34 million persons) in 25 different industrial sectors and over 2 million companies, and is dominated by SMEs. The turnover in 2010 was approximately EUR 6 400 billion (Eurostat). The following charts present some data to inform the policy debate.

Chart 2.2 shows that the share of manufacturing value added in the EU declined from about 18% in 2000 to about 14% in 2009 and then recovered to about 16% in 2011. In section 5.3.6 some possible explanations of this trend are set presented.

[28] Warwick, op.cit.

Chart 2.2: Share of manufacturing value added in the EU, 2000-2011

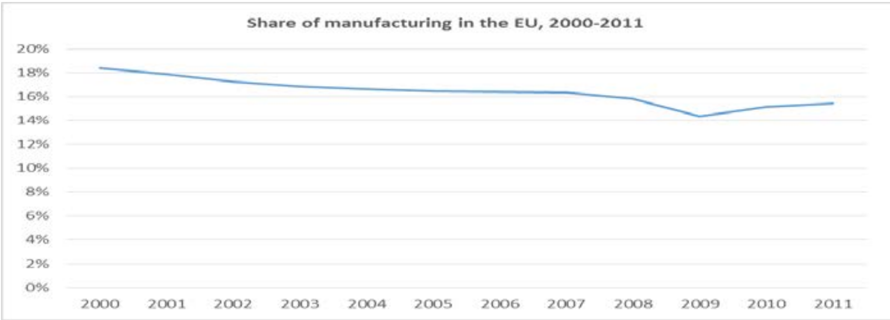


Chart 2.3 suggests that during this period the EU share of Germany in manufacturing value added grew from 27% to 31%, even though Germany's share of manufacturing in its economy remained the same over the period 2000-2012 (see chart 2.5) below. The largest decline was in the UK's share, from 15% to 10%. Italy's share declined more modestly by 1% and that of France by 2%. These changes also reflect the effect of new member states joining the EU during this period, pushing up the share of those that account for <4% from 20% to 24%.

Chart 2.3: Distribution of Manufacturing between Member States 2000-2012 (% shares)

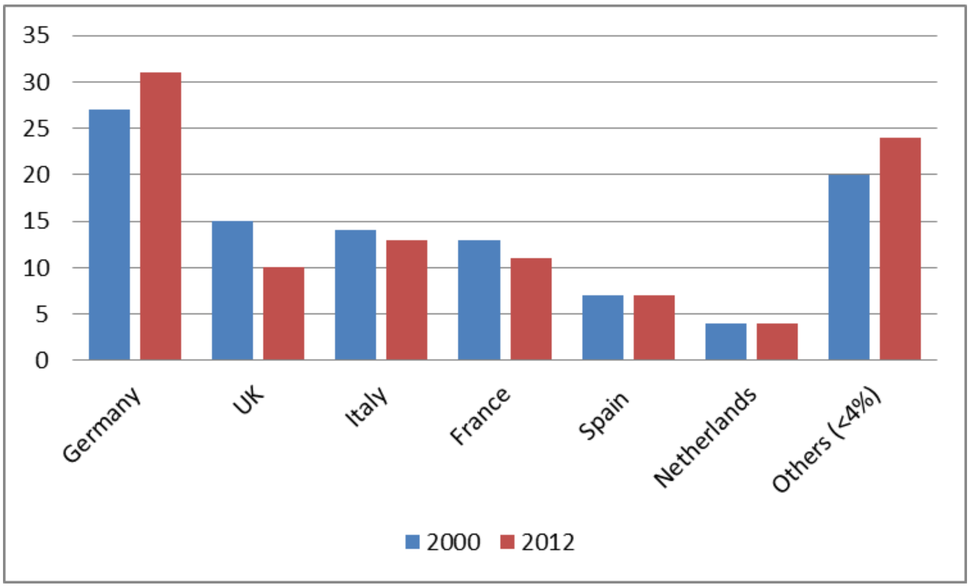


Chart 2.4 sets out the shares of manufacturing value added in individual EU Member States during 2012. It should be read in conjunction with chart 2.5. Clearly there are significant variations.

Chart 2.4: Share of manufacturing in total gross value added 2012 (%)

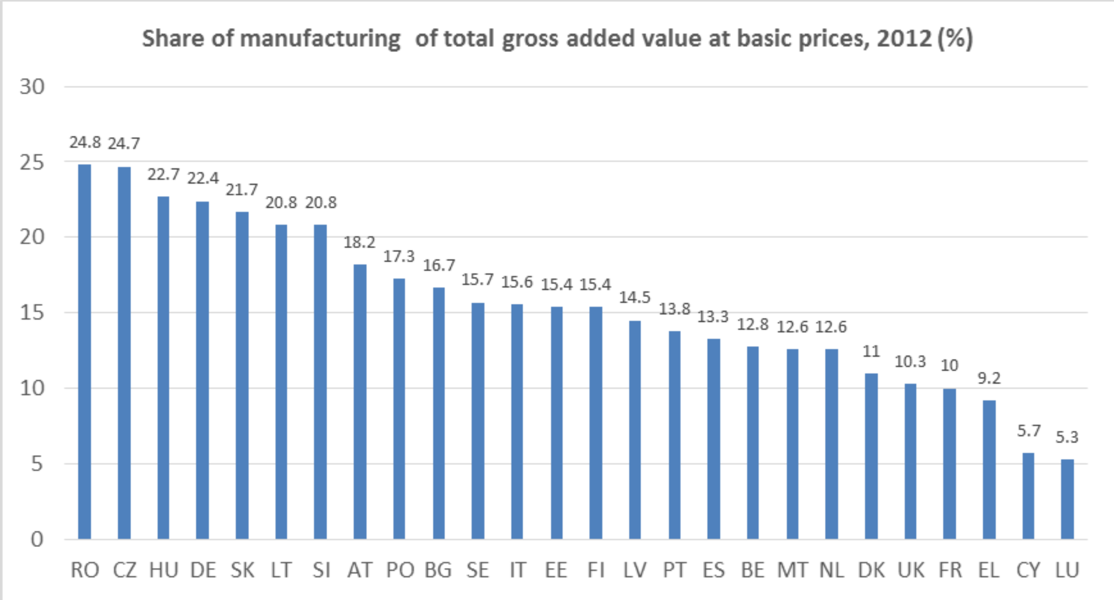
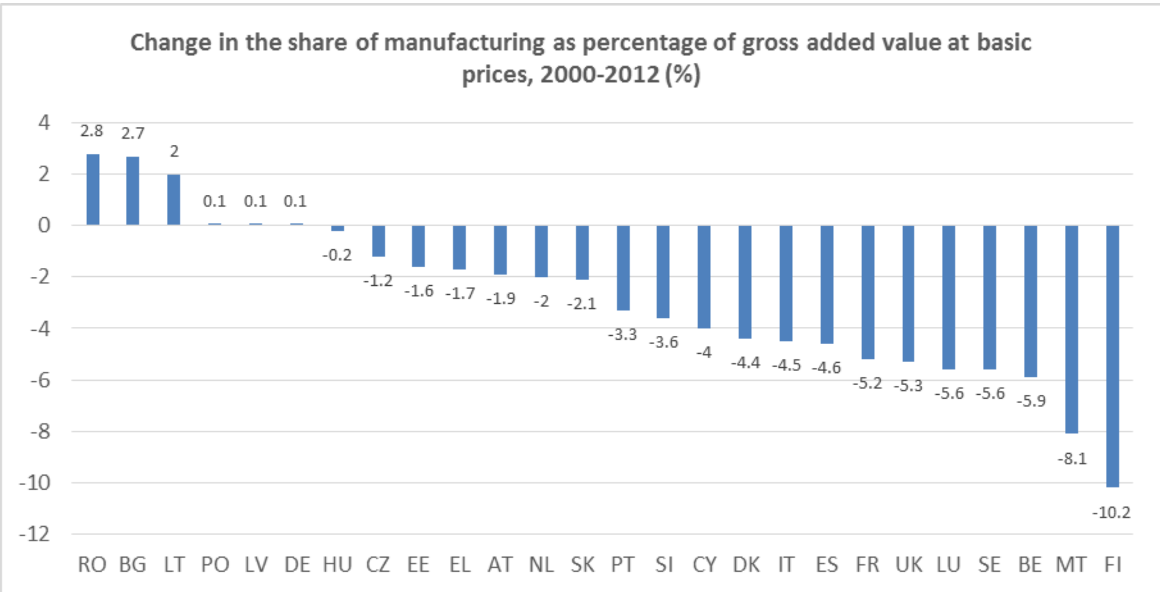


Chart 2.5 shows that among the largest EU manufacturing countries, over the period 2000-2012: the share of manufacturing value added in Germany has remained constant; in the UK it has declined by 5.3% and in France by 5.2%. In Italy the decline has been 4.5% and in Spain it has declined by 4.6%, while in the Netherlands it has declined by 2%. A large share of the overall decline in the share of manufacturing from 18.4% to 15.5% between 2000 and 2011 can be accounted for developments in these major countries. If these individual countries choose not to follow a highly manufacturing oriented value adding policy, what will be the effect on the overall EU share of manufacturing value added?

Chart 2.5: Change in share of manufacturing as a percentage of gross added value at basic process 2000-2012 (%)



2.6 Key questions

In developing views on Industry 4.0, the following questions should be born in mind:

- What do the data have to say about the development of the manufacturing sector in the different EU Member States? Which are responsible for most/ least EU manufacturing? Where have the main changes been in recent decades (increase/ decreases)? Are there specific factors behind that?
- What should be the aims of policy (industrialisation, productivity, sector growth, employment, social welfare, distribution)?
- Who is the target group to be affected by the policy? Which firms, firm sizes, sectors, countries, etc. will be affected, how and how much? Are these sectors (or technologies, inputs, or stages of the value chain), firms or clusters? (Will it succeed in reaching them and will there be others not in the target group that are affected?)
- What would be the rationale that justifies active industrial policy (market failures, capacity building, catch-up, etc)?
- Orientation: is policy horizontal/functional or vertical/selective? Is targeting strategic or in response to market pressures? Is intervention time-limited or longer-term? Conditional or unconditional? Does policy work with existing comparative advantage or explore new areas?
- Policy domain: product or factor markets – labour, capital, land and technology. What role is there for policies to develop entrepreneurship or facilitate co-ordination the creation of new networks?
- How can the success or otherwise of the policy be measured and evaluated?

3. INDUSTRY 4.0

KEY FINDINGS

- Industry 4.0 describes the organisation of production processes based on technology and devices autonomously communicating with each other along the value chain in virtual computer models.
- Industry 4.0 involves a series of disruptive innovations in production and leaps in industrial processes resulting in significantly higher productivity.
- Challenging preconditions for successful implementation of Industry 4.0 have to be met as regards standards, work processes and organisation, availability of products, new business models, security and IP protection, availability of workers, research, training and professional development and the legal framework.

3.1 What is Industry 4.0?

3.1.1 The meaning of the term and main features

The term "Industrie 4.0" was initially coined by the German government. It describes and encapsulates a set of technological changes in manufacturing and sets out priorities of a coherent policy framework with the aim of maintaining the global competitiveness of German industry. It is *conceptual* in that it sets out a way of understanding an observed phenomenon and *institutional* in that it provides the framework for a range of policy initiatives identified and supported by government and business representatives that drive a research and development programme.

Industry 4.0 describes the *organisation of production processes based on technology and devices autonomously communicating with each other along the value chain*: a model of the 'smart' factory of the future where computer-driven systems monitor physical processes, create a virtual copy of the physical world and make decentralised decisions based on self-organisation mechanisms. The concept takes account of the increased computerisation of the manufacturing industries where physical objects are seamlessly integrated into the information network. As a result, "manufacturing systems are vertically networked with business processes within factories and enterprises and horizontally connected to spatially dispersed value networks that can be managed in real time – from the moment an order is placed right through to outbound logistics."[29] These developments make the distinction between industry and services less relevant as digital technologies are connected with industrial products and services into hybrid products which are neither goods nor services exclusively. Indeed, both the terms 'Internet of Things' and 'Internet of Services' are considered elements of Industry 4.0.[30]

[29] Forschungsunion/acatech, *Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0*, 2013, http://www.bmbf.de/pubRD/Umsetzungsempfehlungen_Industrie4_0.pdf p. 9

[30] Forschungsunion/acatech, *Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0*, 2013, http://www.bmbf.de/pubRD/Umsetzungsempfehlungen_Industrie4_0.pdf p. 5

The main features of Industry 4.0 are:

- *Interoperability*: cyber-physical systems (work-piece carriers, assembly stations and products) allow humans and smart factories to connect and communicate with each other.
- *Virtualisation*: a virtual copy of the Smart Factory is created by linking sensor data with virtual plant models and simulation models.
- *Decentralisation*: ability of cyber-physical systems to make decisions of their own and to produce locally thanks to technologies such as 3d printing.
- *Real-Time Capability*: the capability to collect and analyse data and provide the derived insights immediately
- *Service Orientation.*
- *Modularity:* flexible adaptation of smart factories to changing requirements by replacing or expanding individual modules

3.1.2 Development of the concept

Bledowski has suggested that the origins of the idea are to be found in the German government's 2006 High Tech Strategy[31]. Some of the features of Industry 4.0 were identified in Germany's industrial policy in 2010[32] and in 2012 the government made Industry 4.0 one of 10 future projects part of its High-Tech Strategy.[33] A working group consisting of representatives from industry, academics, and science was set up by the German Ministry of Education and Research which in 2013 published a final report outlining 8 priorities of an Industry 4.0 strategy ranging from standardisation to continued learning.

The Ministry of Economics stated the goal of fostering research and innovation "at a pre-competitive stage" and accelerating the process of transferring scientific findings into the development of marketable technologies.[34] That this not only concerns large corporations becomes clear when the strategy explicitly includes the goal of strengthening the innovation power of entrepreneurs and SMEs by creating competence centres for Industry 4.0.[35]

The German government has since institutionalised its commitment to Industry 4.0 by setting up a platform led by Ministries of Economy and Research bringing together representatives from business, science, and the trade unions.[36] The Industry 4.0 platform has divided up its main areas of focus across five different working groups: Reference Architecture; Standardisation; Research and Innovation; Networked Systems Security; Legal Environment; and Work, Education/Training[37]. The platform issued a first report in April 2015.[38] This report introduced the utility of Industry 4.0 to the wider economy and society as one of the key aspects to be further explored in the future and outlined a more refined research roadmap until 2030. This time horizon shows that Industry 4.0 *is a very long-term strategy and the transformation it seeks to foster is still in embryonic form*.

---

31 Krzysztof Bledowski. 2015. MAPI The Internet of Things: Industrie 4.0 vs. The Industrial Internet.
32 Federal Ministry of Economics and Technology. 2010. In focus: Germany as a competitive industrial nation. Building on strengths – Overcoming weaknesses – Securing the future.
33 Bundesregierung. 2014. Die neue Hightech-Strategie. Innovationen für Deutschland.
34 Unit „Convergent ICT" within German Ministry of Economics and Energy. Presentation Matthias Kuom
35 Unit „Convergent ICT" within German Ministry of Economics and Energy. Presentation Matthias Kuom
36 https://www.bmwi.de/BMWi/Redaktion/PDF/I/industrie-40-plattform-flyer,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf
37 http://www.bmwi.de/EN/Press/press-releases,did=697920.html
38 https://www.bmwi.de/BMWi/Redaktion/PDF/I/industrie-40-verbaendeplattform-bericht,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

3.1.3 Related terms

Industry 4.0 is not the only term that describes these new phenomena in industrial production. As mentioned above, both the *Internet of Things* (IoT) – a term coined in 1998[39] – and the Internet of Services describe the digital integration of production and services.

- *The Internet of Things:* refers to IT systems connected to all sub-systems, processes, internal and external objects, supplier and customer networks; that communicate and cooperate with each other and with humans. According to some estimates, the number of devices communicating with each other has surpassed the number of people communicating with each other.[40] According to other projections, by 2020, 30 billion devices – from a jet liner to a sewing needle – will be connected to the internet.[41]
- *The Internet of Services*: refers to internal and cross-organizational services which are offered and utilised by participants in the value chain and driven by big data and cloud computing.

Industry 4.0 is application of the IoT into a manufacturing and service environment.[42] Some other terms often cited in the literature concerned with Industry 4.0 are:

- *The Industrial Internet*: General Electric describes similar phenomena to those summarised under Industry 4.0 as the 'Industrial Internet' (II) in which the industrial and the internet revolutions come together. The difference here is that unlike Industry 4.0, the Industrial Internet goes beyond manufacturing to cover the wider adoption of the web into other forms of economic activity.[43]
- *Advanced manufacturing*: Another term often cited in the literature to describe innovations in technology improving products or processes.
- *Cyber-physical systems* which are made up of software embedded in hardware such as sensors, processors and communication technologies and can autonomously exchange information, trigger actions and control each other independently.[44],[45]
- *Smart factory*: This and the related term 'factory of the future' exemplify some of the technical innovations under Industry 4.0 such as integration of ICT in the production process and how these could play out in practice.

3.2 The underlying logic of Industry 4.0

3.2.1 Disruptive innovation

The Working Group that developed the concept of Industry 4.0[46] regards it as a series of *disruptive innovations in production and leaps in industrial processes* resulting in significantly higher productivity. It is viewed as the fourth time such a disruption took place following the:

---

[39] Howard, Philip N. Sketching out the Internet of Things trendline.
[40] Howard, Philip N. Sketching out the Internet of Things trendline.
[41] ABI Research estimates
[42] Forschungsunion and ACATECH (2013): Securing the future of German manufacturing industry- Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Final report of the Industrie 4.0 Working Group, p.14
[43] Krzysztof Bledowski. 2015. MAPI The Internet of Things: Industrie 4.0 vs. The Industrial Internet.
[44] Krzysztof Bledowski. 2015. MAPI The Internet of Things: Industrie 4.0 vs. The Industrial Internet.
[45] Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0 Final report of the Industrie 4.0 Working Group. 2013.
[46] German Federal Ministry of Education and Research, *Project of the Future: Industry 4.0.*

1. First industrial revolution when steam power combined with mechanical production led to the industrialisation of production in the late 1700s.
2. The Second industrial revolution when electricity and assembly lines resulted in mass production from the mid-1800s onwards.
3. The Third industrial revolution when electronics and IT combined with globalisation greatly accelerated industrialisation since the 1970s.

According to this logic, the fourth industrial revolution links intelligent factories with every part of the production chain and next generation automation that has started to occur since about 2010.[47]

In our view, it is somewhat of an oversimplification to characterise the first and subsequent industrial revolutions in this way, and economic historians will differ as to whether this would be a continuation of the third or the beginning of a fourth industrial revolution. Also, this model does not point out that with each "revolution", national industrial leadership has changed – from England, to Germany and the Continent of Europe, and then the USA. But two key questions to be answered are about the extent to which this would be a "disruptive" technology that changes the rules of the game and leads to a leap in productivity (rather than incremental change), and if so, the extent to which such change can be generalised throughout the economies of Member States (all, some, which, how, etc.) and sectors that can be affected (and to what extent, etc.). Nevertheless, the argument does fit in with the observed evolution of industrial systems away from the Taylorist and Fordist[48] approach that has increasingly characterised production systems since the 1970's.

As regards the *dynamics* allegedly having a disruptive potential in the transformation of production encapsulated by the term "Industry 4.0", it is argued by the proponents of the idea that it is now for the first time possible to link previously isolated elements of the production chain via RFID (radio-frequency identification) chips or so-called mini transponders.[49] This means that each product can have digital information embedded into it that can be shared via radio signals as it moves along the production line, and these products can then communicate with each other independent of human interference. The information thus generated can be analysed with big data and cloud computing processes which allows detecting and addressing invisible issues such as machine degradation, component wear, etc. in the factory floor. To the degree that this is done automatically, smart devices are then capable of managing manufacturing operations and optimising them autonomously by adjusting their own parameters as they sense certain properties of an unfinished product. Moreover, these technological improvements make it possible to customise products to a single unit, drawing the consumer into the production process in a form of 'mass customisation'.[50] This, in turn, allows producers to respond swiftly to changing customer demands and market conditions.

The underlying logic of this manufacturing transformation is characterised by:[51]

- *Horizontal integration through networks*: The networks can be managed in real time – from the moment an order is placed right though to outbound logistics;

---

[47] Siemens, at: Sam Shead, *Industry 4.0: the next industrial revolution*, 11 July 2013

[48] Taylorism – the 'scientific management' approach that breaks tasks down into smallest components; Fordism – the approach to standardised mass production pioneered by the Ford motor company.

[49] Dr Werner Struth of Bosch, at: Sam Shead, *Industry 4.0: the next industrial revolution*, 11 July 2013

[50] Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0 Final report of the Industrie 4.0 Working Group. 2013. P. 5

[51] Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0 Final report of the Industrie 4.0 Working Group. 2013.

- *End-to-end digital integration of engineering across the entire value chain* ranging from design, inbound logistics to production, marketing, outbound logistics and service to after-sales service; and
- *Vertical integration and networked manufacturing systems* where the IT systems at levels of sensor, control, production, manufacturing, execution and corporate planning work together and production, production processes and automation will be designed and commissioned virtually in one integrated process and through the collaboration of producers and suppliers. Physical prototypes will become less important.

3.2.2 Preconditions for Industry 4.0

One key focus of the study is to identify the preconditions required for the successful implementation of Industry 4.0. The presence of these preconditions, and the ability to create such preconditions where they do not exist, vary between Member States. The chart below presents a ranking of challenges identified based on a survey carried out in 2013[52]:

Chart 3.2: Preconditions for implementation of Industry 4.0

- *Standardisation* of systems, platforms, protocols, connections, interfaces seem is crucial and a reference architecture to provide a technical description of these standards and facilitate their implementation to help business implement Industry 4.0 processes.[53] This will not work without a degree of openness and collaboration between companies.[54]
- *Work organisation* will have to change reflecting changes in business models. Complex systems will have to be managed with the help of planning and explanatory models. Real-time oriented control will transform work content and processes & environment, resulting in increased responsibility and continued development required for individuals. This will require a concerted effort amongst stakeholders in order to be successful.

---

[52] Source: BITKOM, VDMA, ZVEI 2013. Found at: Forschungsunion/acatech, *Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0*, 2013, p. 25

[53] Roland Berger Strategy Consultants, *Industry 4.0. The new industrial revolution. How Europe will succeed*, March 2014. p. 7

[54] Dr Werner Struth, Bosch, at: Sam Shead, *Industry 4.0: the next industrial revolution*, 11 July 2013

- Will *products be available* that can both be used in the production process and sold to various buyers?
- *New business models* have to be developed and implemented – what are the costs involved, and who will bear the risks and costs for initiatives that fail?
- *Security/ protection of know-how* in a global competitive situation is critical. Will companies/ governments be prepared to invest if their innovations can be readily duplicated by others that have not had to bear the investment in R&D (including those based in Third countries)? Will the costs of investing in safety of equipment to protect workers be proportionate to the potential gains? Manufacturers will have to protect themselves against misuse and unauthorised access, e.g. with the help of unique identifiers and by training staff.
- The *availability of skilled workers* that can design and operate Industry 4.0 establishments. Who will invest in their skills and training? What are the implications in terms of employment for those without such skills? One emerging theme seems to be that of continued life-long learning which is particularly relevant in the context of Industry 4.0 where highly sophisticated technological systems require very specific skills.[55]
- Who will carry out the *research* required to further develop Industry 4.0 (public/ private)**?**
- How can *a common EU legal framework* to enable the digitalisation of industry be developed and implemented? This is a precondition for companies to implement Industry 4.0 in the Single Market as it would allow them to pool resources to undertake the investments needed to integrate their production systems. The protection of corporate data, liability issues, the handling of personal data and trade restrictions will have to be addressed by regulation. Some, such as the consultancy Roland Berger argue that a “pragmatic” antitrust policy allowing for identification of “industrial champions” to emerge vis-à-vis the US and Asia would be “helpful”. This would be a significant departure from current EU industrial policy. However, the opposite argument can be made that lax antitrust policies benefit large companies creating monopolies and setting standards that benefit them – consequently raising the entry barriers for SMEs and newcomers. Finally, (public) investment in the fixed and mobile broadband infrastructure for industry both within Member States and between them will have to be increased in order to facilitate the implementation of dispersed production networks (completion of the *Digital Single Market)*.

Company investments necessary to implement Industry 4.0 relate to the integration of advanced ICT technologies, the purchasing modern equipment and advanced machine tools, the improvement of energy and material efficiency to save costs, the integration of clean tech practices, and the training of staff and management.[56]

The Boston Consulting Group (BCG) has *estimated the impact* of Industry 4.0 for Germany.[57] The key benefits are grouped into four areas:

- *Productivity*: the benefits are estimated at €90-150 bn over the next 5-10 years based on productivity improvements of between 15-25% excluding material costs,

[55] Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0 Final report of the Industrie 4.0 Working Group. 2013.

[56] Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0 Final report of the Industrie 4.0 Working Group. 2013.

[57] Boston Consulting Group. 2015. Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries

and 5-8% including materials costs. The greatest benefits are expected in industrial components and automotive.

- *Revenue growth*: is estimated at €30 bn or 1% of Germany's GDP per year based on an anticipated increase in manufacturers' demand for enhanced equipment and data applications combined with consumer demand for customised products.
- *Employment*: this is a controversial area as in the past automation and technological advances have at times led to a reduction in employment, at least in the short term. BCG expect a 6% increase in employment during the next 10 years but caution that different skills will be required and that some low-skilled workers may be displaced by machines while others such as mechanical engineers, software developers and IT experts will be in greater demand.
- *Investment*: €250 billion is required during the next ten years by German producers alone (equalling 1-1.5% of their revenues), which is not too far from the € 1,350 bn quoted by Roland Berger for the entire EU over the next 15 years.

The impact of Industry 4.0 and how benefits are realised will differ between countries and industries. Industries with a high level of product variants such as the automotive and food-and-beverage industries will benefit from a higher degree of flexibility whereas industries with a focus on high quality such as semiconductors and pharmaceuticals may benefit from reduced error rates. Some companies are well positioned to serve new markets. The key businesses that will increase in importance include technology suppliers (e.g. Dassault), infrastructure providers (cloud computing, big data storage and processing, telecoms, SAP) and industrial users (e.g. Siemens, VW or BASF)[58] In each category, new players may emerge or established European economies may gain a lead.

Impact may also differ by company size: start-ups and small businesses may develop and provide downstream services[59] and further integrate themselves into value chains or on the contrary may face prohibitive entry barriers to participating in the digital transformation of manufacturing.

Impact between Member States will differ depending on their readiness to adopt new technologies and their general advancement in manufacturing (see below 5.2.3).[60] Industry 4.0 might also benefit remote or underdeveloped regions as technologies such as 3D printing make personalized, decentralised and local production possible (assuming the relevant pre-conditions are present).

[58] Roland Berger Strategy Consultants, *Industry 4.0. The new industrial revolution. How Europe will succeed*, March 2014. p. 17

[59] Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0 Final report of the Industrie 4.0 Working Group. 2013.

[60] Roland Berger Strategy Consultants, *Industry 4.0. The new industrial revolution. How Europe will succeed*, March 2014.

4. LEAD MARKETS

KEY FINDINGS

- To support implementation of Industry 4.0 a lead market strategy is to be developed that supports the demand side for products
- This is to be complemented with a *leading supplier* strategy in a *dual strategy.*

The Industry 4.0 initiative envisages, in addition to a more traditional supply-led strategy, to use a lead-markets approach to support the development of Industrie 4.0. In this section we look at what a lead markets is, and how it is envisaged that the approach is applied in the Industry 4.0 context, and also mention the leading supplier strategy, and how this "dual strategy" is intended to support development of Industry 4.0.

4.1 Lead markets and Industry 4.0

Lead market strategies, instead of supporting a technology-push (supply) route to innovation, aim to exploit demand side opportunities and address deficiencies that discourage entrepreneurial initiatives and investment in innovation. The aim is to co-ordinate demand side policies favouring those business processes that lead to more innovation.[61]

Industry 4.0 actors then develop an Action Plan with achievable outcomes based on developments in legislation and regulation, public procurement, standardisation, labelling, intellectual property management and certification; and, other complimentary initiatives that might be complemented by more conventional supply side policies delivered through support services or access to finance, for example. [62]

According to the Final Report of the Industrie 4.0 working group, [63] "Industrie 4.0 holds huge potential for manufacturing industry in Germany. … The leading market for Industrie 4.0 is Germany's domestic manufacturing industry". The aim is to shape and expand the German lead market through networking by businesses at proximate sites and co-operation between businesses more generally. This will require digital integration of the different stages of value chains, product life cycles, product ranges and the relevant manufacturing systems.

The report identified one particular challenge as the emerging value networks of enterprises that already operate globally, since SMEs often operate just at a regional level. It goes on to point out that "many SMEs are not prepared for the structural changes that Industry 4.0 will entail, either because they lack the requisite specialist staff or because of a cautious or even sceptical attitude towards a technology strategy that they are still unfamiliar with."[64] In order to realise this lead market strategy a key element is integrating these SMEs into global value networks in a comprehensive knowledge and technology transfer programme (e.g. through pilot applications and good practice examples that demonstrate benefits and lead to increased emulation by other SMEs as a result). This would help remove barriers to

---

~~61~~ The Commission adopted a lead markets development strategy as one of the post-Lisbon 2005 relaunch initiatives in 2007[61] following the publication of the Aho Report[61] to the European Council the previous year.

62 The Centre for Strategy and Evaluation Services LLP (2011) carried out the *Final Evaluation of the Lead Market Initiative.*

63 Forschungsunion and ACATECH (2013): Securing the future of German manufacturing industry- Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Final report of the Industrie 4.0 Working Group, p.29

64 Ibid.

acquaintance with and application of CPS methodologies. To enable this also requires accelerated use and development of the technological infrastructure (e.g. high-speed broadband), training skilled workers and developing customised and efficient organisational designs for complex working arrangements.

4.2 The "Dual Strategy" for Industry 4.0 success

Support for Industry 4.0 combines the *lead market strategy* with a *leading supplier strategy.* German equipment producers are in pole position to provide leading solutions for Industry 4.0 products. The *dual strategy* was adopted, aimed at a) improving the competitiveness of German industry *overall* by supporting consistent integration of ICT into its production processes and b) building on German companies' expertise in embedded systems and automation engineering, developing new products in manufacturing equipment that Germany could sell on global markets and that would facilitate a move to Industry 4.0 in other countries. In a sense, the strategy is both defensive (aimed at maintaining competitive) and aggressive (develop new lead markets).

An example of a leading supplier of technologies and solutions initiative is that of the *'Autonomik for industrie 4.0'*[65] launched by the German government and implemented by 14 associations from science and industry. The objective is to foster highly flexible infrastructures that enable the emergence of disruptive products. Running over 3 years, the initiative allocates € 55m to 19 projects covering human-machine interaction, engineering models and a 'speedfactory' which supports highly automated and customised production processes in the textile industry. Measures funded include conferences, workshops, research, and trade fair appearances. Results can be expected in 2017.

The challenge is to combine equipment with IT for a quantum change in innovation which will lead to changes in markets, processes and create new opportunities. This requires three steps:

- To adapt basic IT to the requirements of manufacturing and continue to develop IT with this in mind. To achieve effective economies of scale and scope CPS capabilities will be required at existing facilities to enable migration to Industry 4.0, *and* these capabilities will have to be designed-in at new sites.
- Promotion of research, technology and training initiatives needs to be prioritised to achieve lasting leadership in Industry 4.0. Development of methodologies and pilot applications in automation engineering modelling and system optimisation are required.
- New business models will have to be developed to create novel value networks that use the technology developed to link products with services.

Delivery of Industry 4.0 will only be possible through combining the lead markets and leading supplier strategies. This "Dual Strategy" would have three features:[66]

- Inter-company value chains and networks through horizontal integration need to be developed
- End-to-end digital engineering across the entire value chain of both the product and the associated manufacturing system is required
- Development, implementation and vertical integration of flexible and reconfigurable manufacturing system

65 http://autonomik40.de
66 Op. Cit., p.30

5. INSIDE INDUSTRY 4.0

KEY FINDINGS

Technological change.

- Digitisation has been a major driver of changes throughout the value chain.
- While many businesses recognise the challenges, far fewer, especially among SMEs, are prepared for it.
- There are significant challenges (costs and risks) for firms as regards digital security in: intellectual property protection, personal data and privacy; operability of systems; environmental protection and health and safety.
- Public institutions have been created in many countries to improve cybersecurity.
- There is wide-ranging support for research at both EU and Member State level, but a good deal remains to be done.

Social change

- There is little awareness of Industry 4.0 outside the group of key stakeholders – but much about Industry 4.0 remains to be defined.
- Larger firms tend to be more positively disposed towards Industry 4.0. Unions remain cautious and have reservations.
- While a skills gap as well as a gap in willingness to adjust to the Digital Single Market (DSM) exists (estimates indicate that by 2020, Europe could lack some 825,000 digital specialists to complete the DSM), the skill requirements to adjust to Industry 4.0 are much greater.
- New ways of work are needed, as regards which there are positive and negative aspects; and the gap in domestic (and EU) supplies of skills is currently being addressed through sophisticated immigration strategies.
- The supply of Industry 4.0 skills and capabilities throughout the EU is uneven, which is likely to lead to increased concentration in existing centres.

Change in the business paradigm

- There are challenges for SMEs in participating in Industry 4.0 supply chains (costs, risks, reduced flexibility and reduced strategic independence). In a survey carried out in Germany in 2014[67], using a sample of 1,000 enterprises with a turnover of € 500,000 to € 125m, 35% of SMEs stated that digital technologies play no major role for them. For the smaller companies in the sample, the respective share was 52%.
- The public sector can play a role in creating an ecosystem that will help SMEs transition to Industry 4.0, but little research has been carried out in this area. Standardisation remains a major challenge as regards large scale implementation of Industry 4.0. Here the public sector can also contribute.

---

67 https://www.dzbank.de/content/dam/dzbank_de/de/library/presselibrary/pdf_dokumente/DZ_Bank_Digitalisierung_Grafiken.pdf

- For EU industry to remain competitive with developments in other parts of the world (e.g. USA, China and South Korea), Industry 4.0-type approaches will have to be adopted in sectors where such approaches are employed by competitors.

In section 5 three key aspects of Industry 4.0 are reviewed: technological change, social change and changes in business paradigms. It is important to bear in mind the interdependence between these aspects of Industry 4.0 (Buhr 2015).[68]

5.1 Technological change

This sub-section considers the technological changes which are emerging and expected to emerge with the development of Industry 4.0. Indeed, Industry 4.0 has been very much driven by changes relating to technological capabilities and processes.

5.1.1 Technological changes associated with "Industry 4.0" and potential wider implications

Increased digitisation in manufacturing will put pressure on traditional business models and lead to the emergence of new models. Hence Industry 4.0 brings with technological opportunities some challenges, including a growing delimitation of work and issues of data privacy, protection and security.[69] The increased use of modern information technology in industrial processes since the 1970s is not new. However, the increased adoption by the manufacturing industry of sophisticated ICT is “increasingly blurring the boundaries between the real world and the virtual world in what are known as cyber-physical production systems (CPPSs).” [70] Deloitte describes CPPSs as online networks of social machines that are organised in a similar way to social networks. They link IT with mechanical and electronic components that communicate with each other. An early innovation and example of a cyber-physical system is radio frequency identification (RFID) technology, which has been in use since 1999.[71] Thanks to the development of Internet protocol IPv6[72], machinery (even those that have yet to be outfitted with electronic components) will receive individual IP addresses.[73]

Smart systems can exchange information about stock levels, problems or faults, and changes in orders or demand levels. They can play a key role in coordinating processes and deadlines to boost efficiency. Smart networks of this kind are a central concept in the idea of a smart factory, which in itself is a key tenet of Industry 4.0. Data will become increasingly ubiquitous. There are of course major security and ethical issues related to this (see 5.1.4). Whoever can access and use this limitless data will benefit enormously, above all from flexibility and efficiency.[74]

According to Forschungsunion/acatech, a number of technological changes and impacts may result from Industry 4.0:

- Big *efficiency gains* by achieving just-in time maintenance and near zero downtime
- 3d printing will make *personalized, local production* possible

---

[68] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung
[69] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung
[70] Deloitte (2014) Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies
[71] Deloitte (2014) Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies
[72] Internet protocol IPv6 makes this possible, as it offers a much greater number of potential addresses and easier encryption as well as authenticity verification
[73] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung
[74] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung

- *Machine safety* may increase due to self-optimisation and correction
- The *value chain for production can be smoothened over the production cycle* as product parts communicate when they have been finished and next steps such as delivery can be prepared
- *Virtual industrialisation*: before new plant or factories are set up, it will be possible to design and test these in detail in the digital world – reducing mistakes later on
- *End-to-end digital integration* of engineering across the entire value chain
- *Vertical integration and networked* manufacturing systems[75]

There is a need to be careful when speaking about future developments. In 2010, the German Federal Ministry of Economics and Technology said that it is "virtually impossible to make exact predictions about longer-term developments." Moreover, the trends that can be outlined can be described as 'megatrends'. They are not detailed, can vary between industries and countries, and may overlap or contradict each other.

In addition, external factors such as environmental considerations may impact upon Industry 4.0. For example, there is a growing willingness to pay higher prices if necessary for locally produced goods (shorter transport distances involve less pollution), leading to an increased need for local and regional identification.[76]

5.1.2 Impacts of technological change

Although Germany is the most prominent advocate of Industry 4.0, a number of other European countries are also important in the field (see Annex B). A recent Deloitte study looked at the extent to which Swiss manufacturing companies have positioned themselves in relation Industry 4.0 and what technological and other opportunities are arising. From a commercial perspective, a clear majority of companies investigated believe that a major change is inevitable and that "the digital transformation to Industry 4.0 will increase their competitiveness"[77], although, only a small minority of companies view this change as an impact on their current business. However, this is not a trend confined to Switzerland. Industry 4.0 developments remain abstract for most firms. Quoted in Buhr, Klein (2014), suggest that 90% of the members of the Federation of German Industries recognise the challenges posed by Industry 4.0, but only 12% feel prepared.[78]

According to Deloitte, Swiss manufacturing firms see a huge demand for transformation in research and development, in procurement and purchasing and in production. In contrast, warehousing and logistics, sales and services appear the business segments that have undergone relatively little transformation to Industry 4.0, yet may potentially greatly be affected by it. A lack of standardisation of technologies (interfaces) was considered to be a key challenge in achieving Industry 4.0.[79]

---

[75] Forschungsunion/acatech, *Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0*, 2013, http://www.bmbf.de/pubRD/Umsetzungsempfehlungen_Industrie4_0.pdf, p. 9

[76] Ed. Federal Ministry of Economics and Technology (BMWi) (2010) In focus: Germany as a competitive industrial nation: Building on strengths – Overcoming weaknesses – Securing the future. General Economic Policy, Industrial Policy

[77] Deloitte (2014) Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies

[78] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung

[79] Deloitte (2014) Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies

The views of (Swiss and German) manufacturing industry were that Industry 4.0:

- *Can lead to major opportunities and reduce risks*. Swiss manufacturers envisage that Industry 4.0 will lead to new ways for companies to integrate customers' needs into their development and production processes. For example, through direct data sharing of machinery, it will be easier to analyse data, which will aid quality and avoid faults in the production process. However, increased data sharing is also a risk and the exchange of data will need to be proactively developed in tandem with strategies for combatting security and safety leaks.
- According to Buhr, *the bigger the manufacturing company, the more it takes digitisation seriously*. Conversely, SMEs risk lagging behind developments. Just under 70% of companies with an annual turnover of less than EUR5 million indicated that digital technologies play only a minor or no role at all in their processes of value creation today. Quoted in Buhr, Accenture 2014, point out that especially the metals, chemical and construction industries, as well as the trade sector lag behind in digitisation.[80]
- *Is likely to change the need for skills and IT resources*: a common concern among Swiss manufacturing businesses was the potential lack of skilled/trained staff required to facilitate a digital transformation. According to Deloitte, only one-third of companies have an appropriate IT infrastructure in place for Industry 4.0 and just under half consider their infrastructure not to be wholly suitable. A great deal of investment in both skills and infrastructure is therefore required.
- *Can use impetus from exponential technologies, such as 3D printing*: most Swiss companies in the Deloitte study agreed that "the key technology 3D printing (additive manufacturing) will accelerate the transformation to Industry 4.0". Yet it appears that only very few manufacturing companies are making full use of the scope offered by 3D printing. As there are companies that already been working with 3D printing for several years and are developing the next generation of applications, there is a risk that slower companies may miss the opportunity altogether.
- *May increase competitiveness and impact on local job creation*: the impact of digital changes under Industry 4.0 will affect both local and global value chains (i.e. span both low-cost labour countries as well as high-cost ones. There are a small number of companies that forecast that Industry 4.0 could "slow down the trend towards relocating production to low-wage countries". However this argument can only be supported if the location of goods is down to cost-effectiveness and not the result of a need to produce locally.[81]

5.1.3 Industry 4.0 cross-fertilisation with other sectors

According to an analysis by the Friedrich-Ebert-Stiftung, the view of Industry 4.0 advocates is that "anything that can be digitised will be digitised".[82] As a result the potential scenarios of future developments are sometimes drawn up to be quite ambitious. Yet the conceptions of how Industry 4.0 is to affect companies and sectors, economies and societies differ greatly. Stephan (2014) in Buhr, summarises them into three categories:

1. Disruption: Industry 4.0 enables completely new business and value creation models, eventually (over time) displacing an earlier technology.

---

80 Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung

81 Deloitte (2014) Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies

2. Progress: Industry 4.0 solves the problems of today with the technologies of tomorrow. This is in line with an incremental innovation model, i.e. a series of smaller improvements to an existing product or process that allow for a maintained or improved competitive position over time. Incremental innovation is common within the high technology sector as consumer demand is often high for new features.
3. Destruction: Industry 4.0 is not new and lacks innovative approaches.

We have not identified a study that has charted a clear course on the future impact of Industry 4.0 on other sectors, although according to Buhr, the "current discourse is dominated mainly by representatives of the progressive and disruptive conceptions",[83] indicating there is a high probability of cross-fertilisation or other impact on other sectors in due course.

Predictions can be found on the first sectors likely to see benefits from Industry 4.0 developments. Unsurprisingly, the IT and Telecommunications technology are at the top of this list. Developers and providers of software that can be used for big data analysis, networking and digitisation are highly likely to see opportunities for expansion. Buhr's analysis also forecast that many other industries are likely to impacted by Industry 4.0 developments very soon: machine and facility engineering; electrical equipment manufacturers; the chemical industry; car makers and suppliers; the logistics industry; and, agriculture.[84]

These predictions appear to stem from a study undertaken by Fraunhofer IAO on behalf of BITKOM. Fraunhofer IAO estimates productivity gains of around EUR78 billion in six sectors up to the year 2025. This indicates that a yearly sectoral average of 1.7% could be achieved as additional gross added value.[85] However, growth in some industries can mean decline in others. One possible downside is that former industrial leaders risk being 'relegated' to the role of suppliers, if they are unable to stay competitive with their traditional business model.

The increased emphasis on open innovation processes, along with integration of customers in the production process in combination with big data analytics open up possibilities for new business models. According to Hall/Soskice (2001), "this is also the case in Germany, particularly in the sectors responsible for the success of a coordinated market economy, e.g. machinery, facility and vehicle engineering. A major proportion of turnover for these industries is earned via sales of spare parts, upgrades and services."[86]

acatech, the German National Academy of Science and Engineering – and one of the drivers behind the Smart Service Welt 2025 vision focusing on manufacturing – see potential for carrying over Industry 4.0 to other fields of application into the world of the Industrial Internet. These partly overlap with the findings of Fraunhofer IAO. For example:

- There have already been some developments in automated marketplaces for *logistics service providers in the private transport sector*. These are expected to become established in heavy goods transport in the future**.**

---

[82] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung
[83] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung
[84] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung
[85] BITKOM / Fraunhofer IAO 2014
[86] Hall/Soskice (2001) via Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung

- The application of data-based optimisation of the value chain, to oversee seed quantities, fertiliser type, or indeed the harvest processing and logistics chain will become increasingly widespread in *the agricultural sector*.
- The *healthcare sector* stands to gain benefits if it implements a decentralised monitoring of patients' condition, which would also allow for personalised treatment. This can be done through continuous data collection that can improve diagnoses through intelligent algorithms.
- New business models are developing in the area of *smart grids* sector connected with the *energy trade*.[87]

acatech concludes that "*in certain fields of application it will be possible to implement individual aspects of the Smart Service Welt vision even sooner than in the manufacturing sector*".[88]

However, acatech goes beyond direct application, emphasising that Germany (and presumably other high tech manufacturing countries) equally depends on its ability to exploit industrial key technologies more widely (in tandem with Industry 4.0). This is because technologies are highly interdisciplinary and there is often a mutual dependency between technologies. For example, "modern production engineering integrates machining, electronics, information technology, sensor technology, optical technologies, microsystem technology, nanotechnology and biotechnology. Microsystem technologies facilitate the integration of nanotechnologies and biotechnologies in micro- and macro-environments, making them compatible and usable for new products".[89] Furthermore, investment in other key technologies is important to mitigate risks ('backing the wrong horse'), indicating that R&D and manufacturing investments must of course ultimately go beyond the Industry 4.0 strategy.

To summarise these comments on technological change, it is clear from the literature that *the current Industry 4.0 debate is yet to come up with definite answers.* There is considerable amount of material outlining potential technological innovations, however there is still a lack of sharp definition and understanding of what Industry 4.0 comprehends and will actually result over the next 1-2 decades. Buhr makes the important point that regardless of the technological advances possible through Industry 4.0, Industry 4.0 has to be seen as a social innovation as well as a technological one:

"*Added flexibility may also mean further delimitation of work, acceleration, more intense work with more stress and other new challenges to work-life balance. There are other sensitive areas to keep in mind, such as protection, privacy and security. The potential of these systems for surveillance purposes is also a major question. What does this all mean for innovation policy?*[90]

Ultimately, a more defined and systemic understanding of Industry 4.0 will be needed. Industry, research organisations and other stakeholders will need support if Industry 4.0 is to be a success and it will need to be promoted through well-thought through innovation policies. If Industry 4.0 promotes disruptive technologies, this will be an additional challenge for policymakers and regulators in particular.

---

[87] Ed. Smart Service Welt Working Group (2015) SMART SERVICE WELT Recommendations for the Strategic Initiative Web-based Services for Businesses. Final Report

[88] Ed. Smart Service Welt Working Group (2015) SMART SERVICE WELT Recommendations for the Strategic Initiative Web-based Services for Businesses. Final Report

[89] Ed. Smart Service Welt Working Group (2015) SMART SERVICE WELT Recommendations for the Strategic Initiative Web-based Services for Businesses. Final Report

[90] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung

5.1.4 Digital security

Data security means protecting data from destructive forces (both intentional and unintentional) and from the unwanted actions of unauthorized users. EC Directive 95/46/EC stipulates that: “Member States shall provide that the controller must implement appropriate technical and organizational measures to protect personal data against accidental or unlawful destruction or accidental loss, alteration, unauthorized disclosure or access, in particular where the processing involves the transmission of data over a network, and against all other unlawful forms of processing. Having regard to the state of the art and the cost of their implementation, such measures shall ensure a level of security appropriate to the risks represented by the processing and the nature of the data to be protected.”[91]

While this provision only applies to personal data, data security in the Industry 4.0 context also aims to safeguard other data. A non-exhaustive list is provided below:

- *Intellectual property* – According to the World Intellectual Property Organisation “Intellectual property (IP) refers to creations of the mind, such as inventions; literary and artistic works; designs; and symbols, names and images used in commerce” … “IP is protected in law by, for example, patents, copyright and trademarks, which enable people to earn recognition or financial benefit from what they invent or create.”[92] In many cases companies keep the ‘ingredient’ that makes their product original or distinct secret.

- *Personal data protection and privacy* – With the ubiquity of data, data protection (mainly protected by: Article 8 CFREU, Article 8 ECHR, Article 16 TFEU, Directive 95/46/EC) and privacy (Article 7 CFREU and 8 ECHR) become a pressing concern. One way to protect data is to not process it in the first place. However, in the Industry 4.0 context data processing necessarily takes place. There are several data protection principles to ensure that data is processed in an appropriate manner.[93] The ultimate goal of data protection is to ensure privacy of customers and employees (in case that data of persons was processed) and confidentiality (in case data on business secrets were processed). If data is not protected adequately, companies could be faced with court proceedings and ultimately high fines. Furthermore, data breaches could lead to decrease of customer trust which leads ultimately to further losses.

- *Operability* - With the increasing interoperability of networks linking processes and machines, data security is more challenging but crucial to secure functionality (of machines) and operability (of the company as such). For instance if through criminal intention a bug enters the network of a smart company it could lead to great damage since potentially all machines linked to the network could be infected and stop functioning. Furthermore, if a hacker can get into the production environment (which is not usually associated with security systems) he/she can retrieve sensitive data, manipulate the production process or even sabotage the entire production environment. The damage from this type of attack can be much higher than that of conventional hacking.[94] Therefore, data security is not only important to ensure the protection of privacy and intellectual property but also for the operability of the company.

- *Environmental Protection* – Companies might deal with substances that are environmentally hazardous. If the handling of those substances is determined by

---

[91] Article 17 (1) Directive 95/46/EC.
[92] http://www.wipo.int/about-ip/en/
[93] Carey, P. (2009). Data Protction. *A practical guide to EU and UK law*. OUP, Chapter 4, p. 47-54.
[94] http://www.usine-digitale.fr/article/industrie-4-0-et-securite-informatique-les-nouvelles-menaces.N337102

smart machines data and network security might also be important to safeguard the environment (e.g. avoid the manipulation/malfunction of networks leading to misuse/wrong use of these substances).

- *Health and Safety* - When smart machines and humans interact in the same workspace it is important to be able to precisely predict the machines' actions to avoid danger to health and safety. If networks and machines can be manipulated due to insufficient data security machines could interact differently to how they were originally programmed.

Examples of Data Security and related Risks of Industry 4.0

The following are some examples of data security and related risks in Industry 4.0.

- *Intellectual Property*

In the manufacturing industry data determine the production process for a product, and are just as valuable as the design plans. They contain distinctive, inimitable information about the product and its manufacture. Whoever possesses this information just needs the right equipment to develop the counterfeit product. While design data are often well-protected from unauthorized outside access, production data often lie exposed and unsecured in the computer-assisted machinery. An infected computer on the network or just a USB stick is sufficient to obtain the data. Alternatively, hackers can directly attack the IT network – for instance, through unsecured network components, like routers or switches.[95]

- *Privacy*

In the Industry 4.0 context products and services are often interlinked in form of smart products. This signifies a changing paradigm where not only the product itself but the service linked to it is crucial. An example in this respect is smart meter reading. On the one hand the fact that energy consumption is connected directly to the company simplifies the billing process. On the other hand, smart energy grids help the consumer to save energy when not needed. However, all the data generated draws a precise picture of customers, e.g. when they wake up, when they come home when they eat, shower etc. If hacked this data could help thieves to locate times where no one is home when the burglary is executed. Another example is the smart fridge which identifies products and notifies the consumer (or the delivering supermarket) as soon as a product is empty. This involves data that can allow a detailed picture of the consumer (e.g. vegetarian, halal food etc.). Thus, even sensitive data such as religious beliefs can be inferred from such data and –when hacked- can be used for abusive advertisement or stigmatisation.[96]

- *Operability*

Common safeguards to protect computer systems against attacks do not always work for industrial computing. First of all, in a factory, stopping a process, even for less than an hour, can have very significant financial and logistical consequences. Therefore, a simple computer restart may be impossible. Second, some machines run continuously for decades, and this equipment is accordingly very often obsolete. This obsolescence is the main cause of the vulnerability of the systems, which were designed at a time when the TPC/IP protocol was not used. Third, in the industrial computing environment, it is also not possible to disable the USB ports of all positions when these ports are the only way to interact with the machine. Fourth, while data security policy is mostly integrated in

[95] https://www.fraunhofer.de/en/press/research-news/2014/march/security-tools.html

[96] http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/568337/EPRS_BRI(2015)568337_EN.pdf and http://www.proglove.de/#product

software for companies and generally produces solutions for security vulnerabilities in a reasonable time, this does not apply to equipment (although this is key in the Industry 4.0 context. Fifth, manufacturers are not aware of these vulnerabilities. It has been suggested that "more than 70% of factory systems have no data protection in place."[97] This means that manufacturing companies do not have a clear strategy of which and how people are accountable for data security. A starting point to increase data security in the Industry 4.0 context is therefore to employ a number of methods (such as prevention, detection, remediation and restart) which should be familiar to all staff (this also means more investment in training).[98] Three instances of how malware targeted ICS components and influenced the operability of companies have been reported in the press: Stuxnet,[99] HAVEX[100], and BlackEnergy.

The 2014 report of the BSI (German equivalent of the National Agency of Computer Security) mentions an *attack on a German steel plant*. Sophisticated attackers used spear-phishing and social engineering to gain access to the office network of a steel plant. From this network, they made their way into the organization's production network. Control components and entire production machines suffered outages that prevented the plant from shutting down a blast furnace, leaving it in an undetermined state. This resulted in significant damage to the plant. It seems that the actual physical damage to the blast furnace was an unintended side effect. The true intent may have been competitive sabotage (i.e. technical knowledge of conventional IT security as well as industrial control systems (ICS) and production processes), with the blast furnace as collateral damage. But there is currently not enough data to determine the intention of the attackers, nor is it clear how the attackers managed to carry out the spear-phishing attach. But it is assumed that due to the complexity of ICS desk research is not sufficient to carry out such an attack. Consequently, insider knowledge can be assumed.[101]

- *Environmental Protection*

In 2014, South Korea's nuclear plant operator said its computer systems had been breached, raising fears that hackers, including those with possible North Korean links, could shift their focus to key infrastructure. Officials said only non-critical data about nuclear plants had been leaked (such as: leak of personal details of 10,000 KHNP workers, designs and manuals for at least two reactors, electricity flow charts and estimates of radiation exposure among local residents.) Although the operators of the power plant were confident that no safety-critical data could be obtained by hackers, President Park Geun-hye ordered a complete inspection of South Korea's key national infrastructure against "cyber-terrorism".[102] This example shows that data and network security is of utmost importance where a company deal with environmentally hazardous materials (such as nuclear or other toxic materials).

---

[97] http://www.usine-digitale.fr/article/cybersecurite-le-cas-tres-particulier-de-l-internet-des-objets-industriels.N339109

[98] http://www.usine-digitale.fr/article/cybersecurite-le-cas-tres-particulier-de-l-internet-des-objets-industriels.N339109

[99] http://www.wired.com/2014/11/countdown-to-zero-day-stuxnet/

[100] http://www.scmagazine.com/havex-malware-strikes-industrial-sector-via-watering-hole-attacks/article/357875/

[101] The BSI report can be downloaded using the following link: http://www.wired.com/wp-content/uploads/2015/01/Lagebericht2014.pdf An English summary of its findings can be found here: http://www.wired.com/2015/01/german-steel-mill-hack-destruction/ and http://www.securityweek.com/cyberattack-german-steel-plant-causes-significant-damage-report

[102] http://www.theguardian.com/world/2014/dec/22/south-korea-nuclear-power-cyber-attack-hack

- *Health and Safety*

Recently there has been an example of a robot endangering the life of humans. At a Volkswagen production plant in Germany a 22-year-old man was helping to put together the stationary robot that grabs and configures auto parts when the machine grabbed and pushed him against a metal plate.[103] While in this scenario the malfunction of the robot was not intentional, there could be also cases where hackers deliberately influence the software of robots.

Another example where data security could be crucial for safeguarding health and safety is the case of smart hospitals where machinery and sensors are responsible to assess patient data and treat them accordingly. If hackers intrude the network of such smart hospitals enormous health and life threats could be the consequence.

Costs related to Data Security

In 2014, the Ponemon Institute released a *Global Analysis of the Costs of Data Breaches*. It came to the conclusion that "throughout the world, companies are finding that data breaches have become as common as a cold but far more expensive to treat."[104] The costs of breaches increase yearly, which makes it crucial for companies to invest in a data security strategy. In most countries, the most common reasons for data breaches are a malicious insider or a criminal attack. In addition companies are also concerned about malicious codes and sustained probes, which have increased in recent years. On average, companies are faced with 17 malicious codes and 12 sustained probes each month.[105]

Not only the actual cost of repairing breaches or installing data security software can harm businesses but also the loss of business due to decreased customer trust. The Ponemon report revealed that the loss of customers increases the cost of data breach. In the EU, this was particularly the case for companies in France, Italy and the UK. Industries where loss of customer trust played the biggest role were: health, pharmaceuticals and financial services.

Data security is crucial for all companies. However, it is even more concerning for companies operating in an 'Industry 4.0 context.' Since Industry 4.0 is based on autonomous communication between devices along the value chain massive amounts of data are generated and are monitored more, more automated, and interconnected. In this context cyber-physical systems and the Internet of Things will form the backbone of the smart factory future. Consequently, a cyberattack or other risks to data security will immediately hit the 'nerve system' of smart companies and could potentially have an impact on every aspect of the company instead of only one part of it. Therefore, the acceptability and operability of Industry 4.0 depends on how robust security standards are. While the robustness of data security standards is crucial it is also important to facilitate their accessibility by making the use as simple as possible. Only if all employees are confident and aware of how to safeguard data and how to use the respective tools, security gaps can be minimized. Therefore, data security is not merely a technological challenge but also requires training and raising awareness.

It is not clear from any of the studies assessing the monetary benefits of Industry 4.0 (e.g. in terms of production or efficiency increases) if they include estimates of the increased costs of data and IP protection, health and safety, and increased related insurance costs relate to Industry 4.0 for enterprises, or if some loss of business is also imputed in the calculations.

---

[103] http://time.com/3944181/robot-kills-man-volkswagen-plant/
[104] http://www.ponemon.org/blog/ponemon-institute-releases-2014-cost-of-data-breach-global-analysis
[105] Study can be retrieved from: http://www-03.ibm.com/security/data-breach/

How to Secure Data

As "IT security is one of the critical success factors that will make or break the practical feasibility of comprehensive Industry 4.0 solutions"[106] security should be a key consideration at all stages of a plant's lifecycle, from the initial design phase through to construction, commissioning and daily operation.[107] Nonetheless, a total failure-proof system incorporating security features into a manufacturing plant's automation architecture had also not yet been developed. Although a perfect solution is still missing and although no industrial environment can be 100% safe several steps can be taken to ensure the security of data. Balis provides a guide on how to design a secure system.[108]

Institutional Responses to Data Security Challenges

Given the importance of cyber security in the Industry 4.0 context most EU Member States established institutes or ministries dealing with cyber security. They are mandated with mapping out the risks that exist for businesses and private persons and with establishing strategies to avoid these risks. In the following some developments as regards national and international cyber security institutions are presented.

At the global level, multiple fora deal with cybersecurity such as: the OECD, the Organisation for Security and Co-operation in Europe (OSCE), the United Nations General Assembly, the United Nations General Assembly (UNGA), the International Telecommunication Union (ITU), the World Summit on the Information Society (WSIS) and the Internet Governance Forum (IGF).

At the EU level there are three relevant bodies that all deal with cyber security from different angles: First, *ENISA (European Union Agency for Network and Information Security)* is dealing with cyber security on a wider scale. The agency was set up to enhance the capability of the EU and its Member States and the business community to prevent, address and respond to network and information security problems. Second, the *European Cybercrime Centre* based in Europol is the law enforcement response to cybercrime in the EU. It aims to help and protect European citizens, businesses and governments. Its establishment was a priority under the EU Internal Security Strategy. Third, the EU initiative *CERT-EU (permanent Computer Emergency Response Team)* was established to ensure cybersecurity within the EU institutions, agencies and bodies. The team is made up of IT security experts from the main EU Institutions and it cooperates closely with other CERTs in the Member States and beyond as well as with specialised IT security companies. Recently, CERTs have been developed in both private and public sectors in multiple countries. They are small teams of cyber-experts connected to the internet that can effectively and efficiently respond to information security incidents and cyber threats, often on a 24/7 basis.

At the national level, institutions dealing with cybersecurity have also been established. In Germany the *Bundesamt für Sicherheit in der Informationstechnologie* (BSI) investigates security risks associated with the use of IT and develops preventive security measures. It provides information on risks and threats relating to the use of information technology and seeks out appropriate solutions. This work includes IT security testing and assessment of IT systems, including their development, in co-operation with industry.

---

[106] Olaf Sauer from the Karlsruhe-based Fraunhofer Institute of Optronics, System Technologies and Image Exploitation (Fraunhofer IOSB). Retrieved from: http://www.hannovermesse.de/en/news/news/latest-news/safety-first-data-security-essential-to-industry-4.0.xhtml

[107] ibid.

[108] Alex Balis (2015). Industry 4.0 and Data Security: An Underappreciated Threat. Retrieved from: http://industrialtechnology.events/industry-4-0-and-data-security-an-underappreciated-threat/. See also https://www.fraunhofer.de/en/press/research-news/2014/march/security-tools.html http://www.evolvedb.co.uk/recruiting-solutions/network-application-user-security

In France, the relevant institution is the *Agence nationale de sécurité des systèmes d'information (ANSSI).* It is attached to the Secretary General of Defence and National Security (SGDSN) who reports to the Prime Minister. ANSSI is an interagency coordinator of governmental action and its missions include providing secure interagency means of communications, inspecting government systems, acting as a government CERT, providing certification for systems protecting state secrets, acting as an international point of contact and providing training.

In the UK, *the Office of Cyber Security & Information Assurance (OCSIA)* is in charge of ensuring cyber security. It supports Cabinet Office ministers and the National Security Council in determining priorities in relation to securing cyberspace. Furthermore, it supports education, awareness, training and education and works with private sector partners on exchanging information and promoting best practice. In addition, it works with the Office of the Government Senior Information Risk Owner (OGSIRO) to ensure the resilience and security of government ICT infrastructures such as the Public Sector Network (PSN) and G-cloud.

In the U.S.A. the Office of Cybersecurity and Communications (CS&C) is a sub-department of the Homeland Security Department. It is responsible for enhancing the security, resilience, and reliability of the Nation's cyber and communications infrastructure. CS&C works to prevent or minimize disruptions to critical information infrastructure in order to protect the public, the economy, and government services. CS&C leads efforts to protect the federal domain of civilian government networks and to collaborate with the private sector to increase the security of critical networks. In addition, the National Cybersecurity and Communications Integration Center (NCCIC) serves as a 24/7 cyber monitoring, incident response, and management centre and as a national point of cyber and communications incident integration.

5.1.5 Intellectual property

Industry 4.0 implies several changes to the existing industrial landscape. Since data security became more challenging in the Industry 4.0 context, for Intellectual Property protection it is crucial for companies to add an additional layer of protection to their processes and products. Due to the complexity and blurred boundaries of Industry 4.0, intellectual property expresses itself in many facets as outlined below.[109]

- *Patentability of business models*. Industry 4.0 leads to new business models and new models of cooperation. Business models in a smart factory can be highly complex and contribute greatly to the outcome/product. Consequently, intelligence on specific business models does not only need to be protected through data security measures but also through patents.
- *IP of the final product.* Ownership and licensing issues need to be addressed clearly in contracts with suppliers. The increasing interconnection between machines, software and the physical company could lead to confusion as to who can use for instance business intelligence and to what extent (e.g. are software companies eligible to use data?). Another IP concern emerges between the company and the customer. An example is product personalisation, where customers can - during the production process - personalise their product (e.g. modify the print of a t-shirt or the material of a shoe). In this cases it has to be clarified in advance who owns the IP rights for the final product.

[109] Some of these examples are based on a study conducted by the Fraunhofer Institute, which analysed Chinese patents that were registered in the industry 4.0 context: https://www.iao.fraunhofer.de/lang-en/about-us/press-and-media/1230-top-50-chinese-industry-4-0-patents.html

- *Embedded Systems*. An embedded system is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. Embedded systems control many devices in common use today. Patenting here is complicated since the inventive step is often questionable. Furthermore, embedded systems are often based on dedicated software – either manually written code for a micro-controller or regular software running on Linux, MSDOS, NetBSD or similar operating systems. Here we have a regular issue with software-related inventions – it requires strong technical character of the overall solution in order to be patentable.[110]

5.1.6 Research

The European Union has supported research cooperation in the areas of advanced manufacturing for some years. Since 2013, there has been a European Task Force on Advanced Manufacturing and it has developed a Staff Working Document "*Advancing Manufacturing – Advancing Europe*".[111] This provides a detailed description of all EU activities supporting advanced manufacturing along three strategic objectives:

- Faster commercialisation of advanced manufacturing technologies;
- Removing obstacles to demand for advanced manufacturing technologies;
- Addressing skills shortages and competence deficits in advanced manufacturing.

A key role for the Task Force is to develop an overarching structure to align cooperation – and crucially *coordination* – at the EU level by bringing relevant actors from R&D, industry civil society and the public sector together. It also has a structural role in supporting European efforts to modernise domestic manufacturing industry. Within this latter task, special attention will need to be given to SMEs, which face different risks than larger industry and operate under different conditions. For example, the vast majority of SMEs are orientated locally or regionally. They also face bigger risks when investing in innovation.[112]

The European Technology Platform *MANUFUTURE Platform* has established the *European Factories of the Future Research Association* (EFFRA). EFFRA is an industry-driven association and promoted the development of new and innovative production technologies. The key objective of EFFRA is to promote pre-competitive research on production technologies within the European Research Area. It is a representative in the European public-private partnership, formed under the Horizon 2020 framework, called Factories of the Future.[113]

Recently (October 2015) the *Industrial Leadership* theme under Horizon 2020 launched calls under the 'Factories of the Future' topics for the next two years. In total EUR278 million has been earmarked for investment to research and innovation projects supporting advanced manufacturing in Europe. Several of the calls are for the Internet of Things focus area. This research funding aims to "foster the take up of IoT in Europe and to enable the emergence of IoT ecosystems supported by open technologies and platforms. It will be addressed through a complementary set of activities structured around Large Scale

[110] http://ideaprotection.co.uk/embedded-systems-patentable-or-not/
[111] SWD(2014) 120 final
[112] Expert workshop on SMEs readiness factors for adopting advanced manufacturing products and modernise their business: Challenges and Policy Actions – Output paper
[113] See http://www.effra.eu

Pilots."[114] According to the budget information available, it appears around EUR50m is to be made available 2016-2017.[115]

Other key support measures for Industry 4.0 research include the *Future and Emerging Technologies (FET) Programme* under the current EU managed Framework Programme Horizon 2020. This is a funding line that supports "radically new lines of technology through unexplored collaborations between advanced multidisciplinary science and cutting-edge engineering".

Under Horizon 2020, FET actions have been allocated a provisional budget of EUR 2 696 million.[116] This does not exclusively apply to Industry 4.0 but research under this area is likely to qualify as FET projects can be funded under three broad themes:

- FET Open funds projects on new ideas for radically new future technologies, at an early stage when there are few researchers working on a project topic.
- FET Proactive funds emerging themes that aim to establish a critical mass of European researchers in a number of promising exploratory research topics. This covers areas that are not yet ready for inclusion in industry research roadmaps, but with future potential.
- FET Flagships are EUR1-billion, 10-year initiatives that focus on solving an ambitious scientific and technological challenge. [117]

As regards Member State programmes, one source suggests that the German government has spent approximately EUR 200 million to encourage research in the public (including government) and private sectors.[118] Other (more recent sources, 2015) suggest the German government has spent almost EUR 500m on developing the technology[119] however the ratio between research and 'other' spending is not clear.

According to Brettel et al, the German Cluster of Excellence "Integrative Production Technology for High-Wage Countries" at the RWTH University focuses on four research areas that have a strong link to the topics associated with Industry 4.0 (namely Individualization, virtualization, hybridization and self-optimization).[120] Germany also supports a network of 174 businesses, universities, research institutes and other organisations called *Intelligent Technical Systems OstWestfalenLippe* which is collaborating on working on projects worth EUR 100 million.[121]

Other German co-funded projects include:

- BMBF project RES-COM[122] aims at increasing resource efficiency by enhancing machine-to-machine communication and cyber-physical systems.
- Cluster of Excellence "Integrative Production Technology for High-Wage Countries".[123] Focuses on individualised and virtual production systems, integrated and self-optimising technologies and cross-sectional processes.

---

[114] CALL: INTERNET OF THINGS. Call identifier: H2020-IOT-2016-2017. Publication date: 14-10-2015
[115] CALL: INTERNET OF THINGS. Call identifier: H2020-IOT-2016-2017. Publication date: 14-10-2015
[116] http://ec.europa.eu/programmes/horizon2020/en/h2020-section/future-and-emerging-technologies
[117] http://ec.europa.eu/programmes/horizon2020/en/h2020-section/future-and-emerging-technologies
[118] Techradar April 08, 2015. See http://www.techradar.com/news/world-of-tech/future-tech/5-things-you-should-know-about-industry-4-0-1289534
[119] Wired, MANUFACTURING 21 MAY 15. See http://www.wired.co.uk/news/archive/2015-05/21/factory-of-the-future
[120] Brettel et al (2014) How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective World Academy of Science, Engineering and Technology. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:1, 2014
[121] http://www.its-owl.com/technology-network/
[122] http://www.res-com-projekt.de/index.php/home_DE.html

The Potsdam Institute for Advanced Sustainability Studies is currently undertaking research into *Sustainability Impacts of Industry 4.0*. This examines the sustainability potential of Industry 4.0 against the background of social challenges like climate change and energy transformation. [124]

Relevant research funding is also available elsewhere in Europe:

- A Swiss-Swedish research initiative is currently looking for projects to fund focusing "on the development of innovative products and services within the life sciences as well as within smart factory". The funding for the call is unknown but previous research calls budgets have ranged in the area of EUR25m.
- A number of other national funding agencies show an interest in funding Industry 4.0 related research activities within broader themes ICT programmes. The Research Council of Norway for example, welcomes research proposals on the IoT along with other topics.[125] The ESPRC in the UK also runs relevant research programmes. Two such programmes are outlined in Case Study 3 in Annex A.

Existing research areas

The term 'Industry 4.0' is not a term commonly used in the scientific literature. It is a popular description of 'imminent changes of the industry landscape, particularly in the production and manufacturing industry of the developed world'. Yet in research terms, there is no commonly agreed or explicit definition.[126]

We have found one meta-study of what can be considered to be a review of existing 'Industry 4.0' research. Published in 2014, Brettel et al analysed almost 6,000 articles considered to be relevant to Industry 4.0. They list three research fields, each with sub-fields, as being the current key areas of research:

1. *Individualisation of production*: The industrial production of high-tech products strives to balance the satisfaction of heterogeneous customer needs through individualization with the realisation of scale effects along the value chain. This balance can, according to Brettel's et al research be addressed through the concept of Mass Customization. This is a marketing and manufacturing technique that combines the flexibility and personalization of "custom-made" with the low unit costs associated with mass production.[127]
2. *End-to-end engineering in a virtual process chain*: This refers to advances in integrated engineering along the value chain through advanced methods of communication and virtualization, which is expected to lead to significant optimization potential. With further advances in this field, it is likely that the particular factories or companies will become less important in the production process, as all participating entities can be supplied with access to real-time information and control is distributed to the shop-floor level.

---

[123] http://www.produktionstechnik.rwth-aachen.de/

[124] IASS Potsdam Institute for Advanced Sustainability Studies e.V. Sustainability Impacts of Industry 4.0. See http://www.iass-potsdam.de/en/research-clusters/enabling-technologies-sustainability/sustainable-ict-solutions/sustainable

[125] The Verdikt Programme: Investing in the Internet of the future. See http://www.forskningsradet.no/prognettverdikt/Nyheter/Investing_in_the_Internet_of_the_future/1253599616106?lang=en

[126] Brettel et al (2014) How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective World Academy of Science, Engineering and Technology. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:1, 2014

[127] Brettel et al (2014) How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective World Academy of Science, Engineering and Technology. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:1, 2014

3. *Horizontal Integration in Collaborative Networks*: this research area is concerned with the increased complexity in the network of companies, which is set to increase with the advances of Industry 4.0. Concepts such as 'Collaborative Manufacturing' and 'Collaborative Development Environments' are expected to gain importance especially for SMEs with limited resources. With advances in collaborative networks, it will be important to balance risks and use combined industry company resources to expand the range of perceivable market opportunities. Companies that are in collaborative networks can develop to adapt to volatile markets and shortened product lifecycles. However to remain internationally competitive, companies in collaborative networks will need to focus on their core competencies while outsourcing other activities to collaborators in the network. This may include making changes to business models of manufacturing companies.[128]

Possible future areas of research

A recent study funded by the German Federal Ministry of Education and Research '**S**ecuring the future of German manufacturing industry'[129] argues that, while Industry 4.0 requires industry led implementation, research activities constitute an important arm of the implementation strategies. The study lists several key areas or questions where it believes a stronger evidence base is needed in the medium- and long-term. Key research questions relate to: [130]

- Standardisation and open standards for a reference architecture
- Managing complex systems through modelling
- Delivering a comprehensive broadband infrastructure for industry
- Safety and security as critical factors for the success of Industry 4.0
- Work organisation and work design in the digital industrial age
- Training and continuing professional development for Industry 4.0
- Regulatory framework
- Resource efficiency

The research topics cover both technical and socioeconomic challenges, including data safety and security issues and regulatory issues which often arise with the emergence of new technologies. Although the list of issues is comprehensive, it covers large questions that are likely to require substantial resources to address. Furthermore, the questions are geared towards the implementation of an already articulated strategy.

5.2 Impacts of social change

This sub-section discusses the social dimension of Industry 4.0, and in particular the question of the change in the nature of work involved in Industry 4.0; the supply and availability of the required skills; how closing the skills gap has been approached in

[128] Brettel et al (2014) How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective World Academy of Science, Engineering and Technology. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:1, 2014

[129] acatech – National Academy of Science and Engineering (2013) Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group

[130] Source: acatech – National Academy of Science and Engineering (2013) Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group

Germany; and, some implications for geographic distribution of Industry 4.0 activity throughout the EU.

5.2.1 Public awareness and response – attitudes and dispositions

Public awareness

We have not identified evidence of awareness of Industry 4.0 outside the key stakeholder communities specifically affected at this stage: industry, policy makers, academia and the unions. The general public, and even NGOs, have not as yet, it appears, become aware or responded to the idea. Among the affected communities across Europe, those most directly affected due to the size or strength of their manufacturing industry in their economy tend to be most aware (Austria, Germany, The Netherlands, Italy, France and the UK). There are often related initiatives present, even if not necessarily called "Industry 4.0" in those economies. However, according to Staufen Consulting, 8/10 German companies feel abandoned as regards Industry 4.0[131]

Public awareness could be increased through various programmes, but our view is that, in countries where there is not yet substantial awareness, measures be put in place support the initiative before it is broadcast to the wider community. In particular, concerns about personal data security need to be addressed effectively, as does the question of increased costs of implementing Industry 4.0 as a result of addressing such concerns. Even in Germany, where a great deal has been done, and is on-going, many of the official documents refer to work that is going to be 'carried out in the future' by research institutions on organisational models, skills development, digital integration, creation of technology platforms, etc. There is a significant agenda of actions to be carried out in the near future for Industry 4.0 to be realised in the longer term. If there is too much publicity about this it could raise unrealistic expectations (good and bad) if too much is said now about something that still has to come into being in the future, and its shape is not yet defined. The first full models are only expected to appear in 2016, and large-scale implementation only realised after 2025.

A wide range of programmes is available to raise public awareness – ranging from those through industry associations encouraging members to adopt the vision; to universities to provide publicity and already start to develop workers with appropriate courses for Industry 4.0 skills.

[131] Sarmadi, Dario: Germany's Industry 4.0 in full swing, despite dissent from unions *LINK*

Disposition towards Industry 4.0

The willingness of manufacturers and industry to use and develop Industry 4.0-type initiatives varies substantially according to the degree of knowledge about what is involved and its perceived relevance or irrelevance, advantages and disadvantages.

Smaller and micro firms[132] (with notable exceptions) tend to be less aware of and least disposed to look into such a new initiative as they have fewer resources available for application to such ends. Given the different populations of micro- and small firms between Member States this will result in differences between Member States as regards disposition toward Industry 4.0. (See also 5.1.2 above).

It is generally agreed that the completion of the Digital Single Market is one of the key preconditions for the successful implementation of Industry 4.0 throughout the EU. At the beginning of May 2015, the European Commission announced its plans for developing a digital single market.[133] The 16 priority areas listed in the plan will be followed up by the end of 2016 with specific legislative proposals. The plan is intended to save €11.7 billion every year, contribute an annual €415 billion to economic performance and create hundreds of thousands of new jobs. The transition is meant to ensure Europe remains internationally competitive in the internet age.

However, even the move towards a Digital Single Market is a challenge for many of the 23 million (non-financial) SMEs that make up the backbone of the EU economy. Current estimates indicate that more than 40% of them still do not make use of the opportunities related to digitalisation, as they are not sure what the effects will be on their value chain, even though the benefits of such a transition are proven as "Companies that use digital technology grow two to three times as fast, are more productive and employ more employees".[134] To achieve this, governments, industries, NGOs and other decision-makers from 22 EU member states started the campaign "e-Skills for Jobs in 2015" by signing the Riga Declaration.[135] It includes ten principles including more and better investment in digital technologies and e-skills, combatting youth unemployment in Europe with the help of digital capabilities as well as promotion of e-leadership at the management level in European businesses.[136] When it comes to moving towards something like Industry 4.0, the challenge is far greater.

The view of the unions is also one of caution because questions related to jobs arise: which jobs might be under threat, the implication as regards performance control, responsibilities and stress, which are discussed further below. IG Metall warned against the "dark side" of Industry 4.0.[137] As regards jobs, a recent report for the World Economic Forum[138], taking a wider perspective than the narrow definition of Industry 4.0 to include what might be called the domain of the Industrial Internet, concluded that adjustment will be uneven and industry- and region-specific, possibly also affecting female workers more negatively than men, with overall a modestly positive outlook for jobs. However, significant adaptations in skills will be required as implementation of Industry 4.0 gathers pace.

---

[132] Using the EU definition of SMEs: <50 employees and < 10 employees
[133] http://europa.eu/rapid/press-release_IP-15-4919_en.htm
[134] Sagener, N http://www.euractiv.com/sections/infosociety/eu-racing-catch-digital-single-market-plan-314390
[135] http://eskillsforjobs.lv/about-riga-declaration/
[136] Sagener, N http://www.euractiv.com/sections/infosociety/eu-racing-catch-digital-single-market-plan-314390
[137] Germany's Industry 4.0 in full swing, despite dissent from unions *EurActiv.de by Dario Sarmadi*
[138] http://www3.weforum.org/docs/Media/WEF_FutureofJobs.pdf

Our view is that in addition to issues surrounding costs, staff capabilities and data protection there may be even more fundamental concerns affecting dispositions to adopt Industry 4.0 at stake. One of the most important factors underlying the strength of the SME community is its independence, which in turn is linked to its flexibility and adaptability. The "Dual Strategy" sets out the extent of integration envisaged between firms to realise the aims of Industry 4.0. The concern would be the extent to which companies become bound to and integrated with each other. Would that lead to a loss of control, what would be the costs involved in supplying new customers? What would switching costs be? What would this mean in terms of affordability, and control by larger enterprises of smaller firms in their supply chains. In other words, there are also other factors involved – power, social relationships, etc., in fact a whole business culture which could be off-putting to SMEs, and even larger enterprises. This could be particularly the case in economies such as Italy, where there is such a large share of micro and small firms.

5.2.2 The supply of labour and skills

Skills required for the wider adoption of Industry 4.0

On the basis of the agenda for Industry 4.0 as set out in section 3, it is clear that a very wide range of skills is required for its implementation. These arise throughout the whole value chain – both at operational and support levels, and range from firm infrastructure through system design, modelling, and manufacturing operations management to human interaction skills. In many ways the convergence of IT, manufacturing, automation technology and software requires the development of a fundamentally new approach to training IT experts. Some new jobs need to be designed such as 'user interaction designers'.

It is envisaged that employee roles will change in terms of content, work processes and work environment.[139] Industry 4.0 work impacts flexibility, working time, health, demographics and private life. This amounts to a significant transformation in jobs and skills profiles. There will no longer be the traditional clear division of labour in manufacturing. There will be new operational and organisational structures requiring more decision making, co-ordination, control and support services – a much more complex environment. There will also be a need to co-ordinate between virtual and real machines and plants in production management systems.

In general, this means that there are significantly higher demands placed on all members of the workforce in terms of managing complexity, higher levels of abstraction and problem-solving. Employees will be expected to act more on their own initiative, have excellent communication skills and be able to organise their own work.

Potentially this means there is scope for substantial job enlargement and enrichment, opportunity to increase earnings, and improved working time flexibility, better work/ leisure balance, and generally enhanced opportunities. In addition, there is scope for increased individual responsibility, decentralised leadership, and management approaches to allow greater freedom in decision-making, involvement in and regulation of the workload, leading to more empowered employees, shifting the organisation of work form more Taylorist approaches towards more holistic and socio-technical methods of work organisation.

However, associated with these changes there will be tensions, challenges and threats. When working continuously through a virtual world there is a sense of loss from own experience through the dematerialisation of work processes, which can lead to alienation and a sense of loss of control, which is not healthy in a work force. It may also lead to

[139] Forschungsunion and ACATECH (2013), section 5.5

overwork, productivity losses and reduction in creativity in favour of “process”. Within the work place there may be increased polarisation between the highly-skilled and administrative/ functional employees, and an erosion of barriers between home and work life with negative effects on physical and mental health.

There is also a threat to headcount: less simple manual tasks will be available for semi-skilled workers, which could lead to socially unacceptable outcomes and hamper the implementation of Industry 4.0.[140]

The IG Metall chairman Wetzel warned that the impending digital revolution holds the risk of a “strong density of performance and new ways to monitor and measure performance”. The economy could become increasingly dependent on new and more flexible forms of working such as “click workers” and “cloud workers”. Such jobs are not paid as well and are hardly socially insured. In the worst case, Wetzel predicted a massive reduction in employees. “Every second job is at risk; we do not even know what kind of an automatisation wave is really in store,” the IG Metall chairman said. We must be sure that people continue to mould technology and that technology does not come to control people, Wetzel emphasised.

Maybe because of reasons such as these one recommendation is that before it is implemented the effects of Industry 4.0 on the German social security system should also be assessed. It may also be worth considering, from this point of view, what will happen if a body of workers (and part of industry) is trained in and adapts to Industry 4.0 skills and the skills become redundant due to changes in the market.

The actual educational profile for a typical Industry 4.0 worker probably still needs to be developed (see below). While the typical Industry 4.0 worker would probably be a graduate from a STEM[141] (or in Germany – MINT) background, Industry 4.0 requires substantially more than this as the skill profile also encompasses managerial capabilities (being able to see the organisation as a whole), being able to understand industry, and how different industries interrelate in terms of value chains and manufacturing and other processes, communication skills and customer skills. It is not just a question of training a “digital worker”.

Our view is that this constitutes a requirement for quite a wide mix of skills. Traditionally recruitment has tended to be based on identifying work skill requirements that different personality types are more suited to (e.g. using the Cattell 16 PF, or Meyers-Briggs approaches) because people have a natural predisposition to different kinds of work. It appears that the skill requirements for working in Industry 4.0 require more than one - and in fact several - skill sets. It is questionable whether there are very many individuals with such a mix of traits, never mind a whole workers’ corps to underpin a whole industry.

Nor should the changes in requirements in terms of managerial skills be underestimated. Inside the enterprise someone needs to design the processes in question, and manage them and the staff involved. Outside the enterprise, new types of relationships between enterprises (suppliers, customers and competitors) that have become virtually integrated – which may involve unprecedented levels of transparency and openness – have to be created and managed.

Prevalence of these skills in the European labour force

According to recent research by the European Commission, digital know-how to underpin the Digital Single Market is in short supply. Commission estimates indicate that by 2020,

[140] Forschungsunion and ACATECH (2013), p.53
[141] Science, technology, engineering, mathematics

Europe could lack some 825,000 such specialists.[142] Without them, an efficient and rapid digitalisation, as well as successful adaptation of the labour market, could remain wishful thinking, experts warned. Soon, the argument goes, the digital revolution will affect all economic areas, indicating that EU competences are urgently needed.

However, the digital skills required for Industry 4.0 are of a much higher calibre and a more interdisciplinary character than those required for basic digital literacy. Hence the debate as to whether there is a shortage of STEM workers or not while relevant is not sufficient.[143]

Documents dealing with Industry 4.0 suggest that the official view is that the skilled labour force required to underpin Industry 4.0 is not yet in existence, and a good deal needs to be done to create it (see below). In Germany, there is evidence from DIHK surveys that one third of companies (in some regions) already see skills shortages as a risk to their continued business activities in areas such as where a university degree is required (e.g. software developers, programmers, STEM disciplines).[144] These trends are expected to be exacerbated in the future due not only to the demands of industry but also demographic trends (see below).

Member States in which these skills are found

As regards identifying in which EU Member States Industry 4.0 skills are prevalent, this is difficult to estimate because there are basically two ways of understanding MINT/ STEM[145]. The first of these refers to the formal degree and field of education (e.g. MA in automotive engineering). According to this definition data listed in the fields of education qualify as MINT. The entry level/degree is vocational training. But, secondly, labour market statistics comprise job types. Unfortunately, an employee's formal degree does not necessarily correspond to his or her job type. For example, a professor in mechanical engineering typically holds an engineering degree but is listed in a teaching job – rather than an engineering job – from a labour market statistics point of view. The manager of an industrial company usually holds a MINT-degree but is listed in a "business and management job". In Germany, there are 1.7 million employed engineers (formal degree) but a mere 1.2 million employees doing an „engineering job (with some formal degree physicists, IT-specialists amongst them). Summing up, the job-based MINT-approach neglects a vast part of the labour market's real MINT-demand.[146]

It appears likely that workers with Industry 4.0 skills are drawn primarily from the pool of STEM/ MINT sills in a country, and would constitute a smaller subset of that group. Hence, countries/ markets with a large workforce with those skills are the ones most likely to have an Industry 4.0 actual/ potential labour force.

According to a study for the European Parliament, in the EU as a whole employment in STEM professions is increasing, despite the economic crisis, but many of those are approaching retirement age – some 7 million MINT job openings are forecast for 2025.[147] While the share of MINT/ STEM (University) graduates is increasing in 15 Member States, since 2005, the supply of vocationally trained STEM students is declining. At university, some 37.5% graduate in STEM areas, but only 12.6% are female. Most Member States

---

142 http://ec.europa.eu/digital-agenda/en/digital-jobs-0

143 http://www.theguardian.com/careers/work-blog/stem-skills-shortage ; Steven A. Camarota and Karen Zeigler (2014); Is There a STEM Worker Shortage? A look at employment and wages in science, technology, engineering, and math, Center for Immigration Studies.

144 DIHK Survey 2013 The Economic Situation and Expectations for 2013, p.26

145 MINT is the German equivalent of STEM. The explanation which follows was obtained from the Institut der deutschen Wirtschaft Köln e.V., which is responible for the German industry report.

146 Kompetenzfeld Bildung, Zuwanderung und Innovation, Institut der deutschen Wirtschaft Köln e.V.

147 European Parliament (2015); Encouraging STEM Studies for the Labour Market, D-G Internal Policies, p.6

report recruitment challenges, especially for those with engineering and ICT educational backgrounds.[148]

The European Parliament study points out that while the overall percentage share of graduates is remaining the same, there are significant differences between Member States. For example, less than 15% of graduates in the Netherlands and Luxembourg are in STEM disciplines, while more than 27% in Sweden, Finland, Greece and Germany are. There are also significant trends in different countries, with for example the share in Austria declining from 32.2% to 25.6%, while that in Germany increased fom 18.1% to 21.2%.[149] The share is above the EU average of 2011 in 15 Member States, icluding Germany, France, Italy and Spain. The high demand is coming from Germany (19%), France (16%), Italy (8%) and Spain (8%).[150]

There is evidence that some countries are already drawing qualified staff from other countires – both within and from outside the EU (see below) in an effort to meet demand.[151] In Germany for example, according to the Spring 2015 MINT report from the Cologne Institute for Economic Research (IW) there is a gap of 137,100 qualified workers with a natural sciences or technical degree in the labour force supply – the highest level since December 2012. The current gap in skilled workers would be larger, the MINT report pointed out, if Germany did not gain skilled workers from abroad. The number of foreigners in the MINT workforce increased by 11.3% from the fourth quarter of 2012 to the third quarter of 2014, over four-times that for German workers in these fields. The report states that migrants from Central and Eastern Europe, particularly Poland, Romania and Bulgaria, play a large role. This is due in large part to the recent opening of the labour market to workers from these countries. Those who move to Germany from these countries are predominantly hired as skilled workers. MINT workers from Spain are also a proportionately large group on the qualified labour market, primarily due to the on-going Spanish economic crisis. Among countries outside the EU, India stands out with 31.6% growth in its citizens employed in the Federal Republic. This increase is likely to be the result of general improvements to immigration conditions, as well as local campaigning for MINT workers (see below).

The influence of demographic trends on the availability of these skills

The view of the EP report and most of the Industry 4.0 publications is that if demographic patterns in the EU persist they will lead to shortages in the supply of workers as many retire over the coming years, and an insufficient number is supplied by the educational institutions.[152] Moreover, they will need several years' experience before becoming as productive as those that have retired.

In Germany, a key contributing demographic factor is considered to be access to full retirement benefits at the age of at 63. According to Michael Stahl, managing director of education and national economy of the employers' association Gesamtmetall, at the presentation of the MINT report in Berlin on 20 May 2015: "Already in the first quarter after the regulation was introduced, around 10% of the actual, available MINT workers aged 63 and over were lost".

---

[148] Ibid., p.6
[149] Ibid., p.12
[150] Ibid., p.12
[151] Sarmadi, D. "Immigrants boost Germany's skilled labour force", EurActiv.de, 22 May 2015 - 07:52 (translated by Erika Körner).
[152] Ibid., p.12

Increasing the availability of skills

The ability to obtain suitably qualified staff is a key underpinning element of Industry 4.0 and most commentators are of the view that there is, and will continue to be, a shortage of those with those skills. There are basically three ways to increase the availability of Industry 4.0 skills.

- Increase participation by parts of the labour force in Industry 4.0 that are not in it at present
- Increase the provision of training and education
- Through immigration (from other parts of the EU or Third Countries)

The segments of the population that could be targeted with a view to increased labour force participation are primarily older workers (e.g. those that have recently retired), women that are not participating in the labour force at present, and women that are currently in the labour force that could be persuaded to follow a career in Industry 4.0.

As regards training and education for careers in the envisaged Industry 4.0 work environment, official reports suggest that this requires development of new learning content and didactic methods. The acatech report suggests that due to the interdisciplinary nature of the work completely new qualifications are required.[153] It will also have to include continued professional education (CPD) for adults, and Life Long Learning will be necessary. This will require self organisation by workers to acquire skills over the internet. Development of new standards to assess formal and informal learning will also be required. Ways to teach social and emotional skills to the computer, systems, and machine designers and programmers will also have to be developed so that they can communicate effectively and relate to customers and other team members in a co-ordinated environment across value chains in different (competing) firms that are collaborating. As human resources managers know, this is quite a challenging set of requirements.

The third approach is to augment the supply of those with the relevant skills through immigration. According to the BMWi, as regards Germany, "It will be impossible to close the skills gap by exclusively relying on the workers who already live in Germany".[154] There is a need to look abroad to countries where these skills are in surplus supply. Germany is concentrating on, outside the EU, Vietnam, Indonesia and India. But as noted above, there are MINT workers immigrating from central and Eastern Europe, as well other countries such as Spain, that have the required skills but few opportunities in their own countries. Other potential source countries are China and Brazil.

However, it can be a challenge, in the first place to accept that foreign workers are required, and secondly, to actually accommodate them in a friendly and hospitable manner. For example, economic analysts have warned that eastern German states, in particular, are wasting the potential of foreign skilled workers and run the risk of experiencing a devastating drop in their skilled labour force. "Mental reservations against immigration are the most significant there," explained Thomas Sattelberger from the Confederation of German Employers' Associations (BDA)[155]. No doubt this could be an issue in other parts of the EU with a mismatch in the labour force between skills required (Industry 4.0) and available (semi-skilled workers).

---

[153] Forschungsunion and ACATECH (2013), p.51

[154] http://www.bmwi.de/EN/Topics/Tackling-the-skills-shortage/skills-policy,did=633758.html

[155] http://www.euractiv.com/sections/innovation-industry/immigrants-boost-germanys-skilled-labour-force-314781

These reservations are considered critical in the Federal Republic's eastern states, where companies are faced with a wave of retirement among MINT workers. While in western Germany 16% of the MINT labour force is on average older than 55 in eastern Germany the rate is 20%. Lander in the west with a strong reputation for innovation such as Baden-Wuerttemberg, Hesse and Bavaria have between 8% and 11% foreign workers in their MINT labour forces. In larger eastern German states foreign workers only make up 1.4-2.2% of that group. In conclusion, the MINT the report states, "without special efforts to be immigrant-friendly, the innovative strength in eastern German regions threatens to erode".[156]

While for large firms and global giants these routes to increasing the supply of Industry 4.0 workers may be a realistic option, for SMEs they present substantial challenges.

The European Parliament Report mentioned earlier contains an overview of various approaches aimed at improving the supply of STEM skills.[157] A good example of a comprehensive plan to develop the supply of Industry 4.0 workers is the German Federal Government's six step approach.[158]

- *Skills policy* which includes many public and private stakeholders and is aimed at increasing the supply of required skills in the regions where most needed – in some regions the shortage of skills is seen as a risk to business sustainability. The DIHK survey found that 41% of IT service providers are seeking qualified personnel.[159]

- *The qualified professionals initiative* is an inter-departmental initiative that helps companies recruit skilled labour and helps skilled professionals market themselves; informs and educates companies – especially SMEs – on the need to recruit and retain skilled professionals (a future-oriented HR strategy); encourages women and older workers, and those from an immigrant background, to enter or re-enter the labour market and/ or earn additional qualifications; and, fosters regional co-operation between companies, universities and industry associations.

- Two internet portals in support of this have been set up: "The Qualified Professionals' Initiative" (in German, providing tips for skilled workers) and "Make it in Germany" which provides multilingual information on vacancies, and presents a positive image of working in Germany, as reflected in obtaining the Blue Card, the revised Employment Ordnance, and assessment and recognition of qualifications obtained abroad (there are local advisors in Viet Nam, India and Indonesia).[160]

- *The Centre of Excellence on securing skilled labour* aims at tapping the skills reserve in Germany. It supports SMEs in recruiting skilled labour, becoming a sought after employer improving competitiveness through staff. The Centre tracks how SMEs are doing, what future developments could look like, identifies actions to respond to challenges faced by SMEs, develops options and possible solutions, and helps SMEs learn from each other. It also publishes information and holds regional workshops.

- *Immigration and a culture of welcome* has become an important element in meeting the gap in skilled labour. This includes: a support hotline for qualified professionals from abroad; providing support with the Blue card application; support in obtaining recognition for qualifications obtained abroad; and a review of the Employment Ordinance which has made it easier for qualified professionals to work in Germany.

[156] http://www.euractiv.com/sections/innovation-industry/immigrants-boost-germanys-skilled-labour-force-314781.
[157] Op. cit., p.27, table 3
[158] http://www.bmwi.de/EN/Topics/skills-shortage.html
[159] Op. cit., p.27
[160] http://www.make-it-in-germany.com/en ; and http://www.fachkraefte-offensive.de/DE/Startseite/start.html

- *The alliance for initial and further training* builds on Germany's dual vocational and training system to strengthen provision of vocational training in Germany. It is an alliance between various stakeholders (business, lander, trade unions and the Federal government) to ensure that vocational training fit for the future is provided and promoted to young people and their parents and throughout society. It does not only focus on high-achievers.
- *Training and vocational policy* aims at providing a framework to encourage more companies to hire trainees to ensure that German business can meet its demand for highly skilled workers in the long term. It provides clear and transparent training regulations and training opportunities for all.

5.2.3 Mobility intra EU

Early adopter spill-over of Industry 4.0

A report by Roland Berger maps the extent of progress with implementing Industry 4.0 in different EU Member States in terms of two criteria: “industrial excellence” and “value networks”.[161] Within the category of “industrial excellence” is included: production/ process sophistication, degree of automation, workforce readiness and innovation. The category of “value networks” includes high value added, industry openness, innovation networks and internet sophistication. Accordingly, they assigned EU Member States to four categories:

- *Front runners*: Germany, Sweden, Austria and Ireland. These countries are judged to have advanced, and are advancing well along the path of Industry 4.0.
- *Potentialists*: include Belgium, Denmark, the Netherlands, the UK and France. Their industrial base has been weakening but within the corporate sector is a modern and forward-looking mind-set that holds potential. (Finland is between the front runners and potentialists).
- *The Traditionalists* are mainly East European. This group includes the Czech Republic, Slovakia, Slovenia, Hungary and Lithuania. They are judged to have a sound industrial base but few have launched initiatives to take them into the new industrial era. (Some of these are already supplying German with Industry 4.0 workers).
- *The Hesitators* are a mixture of southern and eastern European countries (Italy, Spain, Estonia, Portugal, Poland, Croatia and Bulgaria) considered not to have a reliable industrial base and suffer from sever fiscal problems that inhibit them from a future-orientation. (Some of these also are already supplying Germany with Industry 4.0 workers).

While the definition of categories and which economies to include, and the reasons for including them, are debatable, the categorisation does make clear the point that different Member States have achieved different results as regards integrating their manufacturing industries and the internet, and that continued movement into that direction (rate of movement and degree of change) will not be even between the different MS of the EU.

The challenges faced by the different countries are quite different. For example, the situation of Italy, the second largest manufacturing nation in the EU, with its large share of micro and small firms, is very different to that of Finland or Germany, with a lower overall share of such enterprises in their economies, or France and the UK which have important (although declining) shares of manufacturing for different reasons, often related to policy choices and views (which may be changing) about the role of manufacturing in the

161 Roland Berger (2014); Industry 4.0. The new industrial revolution. How Europe will succeed, pp.16-17.

economy of the future that may not correspond to those of for example Germany. The situation in Ireland, with an economy about a third of the size of Paris, dominated by foreign multinationals producing for export markets is, again, very different. Each member state has its barriers and advantages. But there is also a pan-EU dimension to this in terms of for example development of standards and the implementation of the Digital Single Market.

One way in which Industry 4.0 is already spreading is through the implementation of such practices in foreign subsidiaries of plants owned by companies already implementing Industry 4.0, for example through a Czech subsidiary of a German multinational. Hence, increased cross-border investment within the EU by “Frontrunners” in “Traditionalist” economies can help spread practices. If plants carrying out such cross-border investments could support local and regional industry in adapting its supply chains, and work with national educational and training establishments, that would be a positive step to encouraging development and diffusion of this technology. However, it should also be born in mind that not all firms (and labour organisations) in “follower” countries will perceive Industry 4.0 sympathetically – for them it may be a threat to their way of doing business and there could be resistance to such business practices and domination by foreign multinationals.

There have also been workshops between representatives of different countries on Industry 4.0 (e.g. China and Germany) to encourage sharing and uptake.

Concentration or decentralisation?

An important question going forward is whether Industry 4.0 will led to an increased concentration of such plants in some regions of Europe or whether it will lead to a spread of such establishments to parts of the EU where there is not yet a great deal of manufacturing. We have not been able to identify any EU research that directly addresses this question, but evidence from the USA as regards the location of Advanced Industries is that “the geography of advanced industries – notwithstanding its broad ranging diversity – has narrowed from what was once a more widely spread enterprise of regional prosperity. In 1980, 59 of the country’s 100 largest metropolitan areas had at least 10% of their work force in advanced industries. By 2013, only 23 major metropolitan areas contained such sizeable concentrations of advanced industry activity. As a result, the U.S. economy is more reliant on a smaller number of advanced industry clusters today than at any point in recent history.”[162] There has been a marked specialisation between different regions as regards what aspects of advanced industries are specialised in.

This clustering and concentration phenomenon which reflects Myrdal’s process of “cumulative causation”[163] to the centre rather than a levelling spread outwards from the centre is well known in industrial development and it is unlikely, in our view, to differ markedly in Europe from that experienced in the USA. It is already reflected in the developments in Germany, where the need for skilled labour is leading to attracting immigrants from elsewhere in the EU and further afield. Hence Industry 4.0 is likely to result in increased concentration of such activities in areas that are already strong, or getting stronger.

Increased mobility between Member States

[162] Brookings Institute (2015); America’s Advanced Industries. What they are, where they are, and why they matter, p.32 (Muro, M., Rothwell, J., Andes, S., Fikri, K. and Kulkarni, S.j

[163] Multiple changes are set in motion by a single event: a multiple effect results from introduction of a new variable (e.g. industry or technology)

The preceding sections suggest that labour with the required skills is already quite mobile as regards moving between Member States from surplus Industry 4.0 skilled countries to those with a deficit. Countries have already developed policies to facilitate such movement of labour, as set out in the paragraphs dealing with increasing the availability of skills (as per the example of Germany mentioned).

To increase the mobility of industry so as to establish Industry 4.0 plants in other parts of the EU requires creating the preconditions for such plants elsewhere in the EU. These would include: provision of adequate digital infrastructure, provision of appropriately skilled workers and willingness of a network of local enterprises to link up with such plants. As the preceding paragraphs made clear, the extent of the gap to be filled to enable this can vary substantially between different Member States.

Public sector take-up

The public sector tends not to be directly involved in manufacturing, but as a major purchaser of manufactured products can exert an influence directly through buying power (subject to legislation as regards state purchasing behaviour). As indicated in the section dealing with lead markets, the state also has a potential role here in creating an environment that encourages adoption of Industry 4.0 practices.

5.3 Impacts of business paradigm change

This sub-section looks at business responses to Industry 4.0, and how SMEs are positioned as regards supply chains of lager enterprises that have adopted (or are going to adopt) Industry 4.0. A role for the public sector in creating an ecosystem for SMEs is suggested. The critical question of standardisation is then addressed. Finally, the question is asked whether adopting Industry 4.0 will lead to further leadership for the EU or if it is actually just a requirement to maintain existing leadership, or if, given the competitive trends from countries such as China, leadership will inevitably be shared with those emerging economies through the international diffusion of technology by multinationals.

5.3.1 Business response to Industry 4.0

The documents reviewed suggest that it is primarily large enterprises that have hitherto come out strongly in favour of Industry 4.0, and in particular those directly involved in producing the services and equipment in question (see 5.1.2 and 5.2.1).

Industry 4.0 can present a major opportunity for many firms. If deployed effectively, it should contribute to greater productivity through resource efficiency. According to Deloitte, companies in traditional industrial economies, including Germany and the US, expect Industry 4.0 to bring many advantages, stretching from improved competitiveness to a reversal of the trend to relocate production to low-wage countries and the opening of more domestic production locations in Europe and North America.[164] Re-shoring is already a contributor to increased demand for robots in Europe and North America.[165]

However, Industry 4.0 also presents business with great challenges. The preceding subsections have dealt with these in the areas of technology and work force, but the challenge for management should also not be underestimated. This is not only an intellectual challenge, in the sense of designing and operating (often virtual) processes and systems, but also about ways of doing business, about how to collaborate with customers and the supply chain more closely and an integrated manner, and weighing up the risks

[164] Deloitte (2014) Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies

[165] Burns, A. “Uncaged. New statistics from the International Federation of Robotics Illustrate converging patterns of data, efficiency and demand” Site Selection http://siteselection.com/onlineInsider/uncaged.cfm

involved in such a process that could potentially see an enterprise lose its strategic freedom.

5.3.2 Sustainability (costs, environmental, long term)

Costs of information security

The paragraphs dealing with cybersecurity (5.1.4) have indicated what the issues and risks concerned as regards Industry 4.0 are. These are material and substantial costs both at the level of the enterprise and society as a whole (in terms of institutions) required to combat cybercrime. In addition, such requirements will continue to exist into the future and are unlikely to decrease as the systems become more complex and the criminals more sophisticated. These costs may present barriers for SMEs, especially micro and small firms, to participating in Industry 4.0.

As mentioned, we have not found separate data or cost estimates for ensuring cybersecurity and it is not clear if these costs have been factored into calculations about the benefits of Industry 4.0. The software and programming experts required for cybersecurity will also create an additional demand for labour to those already required for Industry 4.0 purposes as such (see 5.2.2).

Environmental impact

The transformation to Industry 4.0 is supposed to lead to agile and adaptive manufacturing, which should then also be resource efficient. Although literature discussing Industry 4.0 and sustainability in depth is very sparse, the scientific view appears to be that it is unclear in what ways and to what extent Industry 4.0 will impact on long-term sustainable development.

Sustainability and manufacturing more generally is an important issue. Data from Eurostat show that the share of EU-27 manufacturing (NACE C) in all EU emissions was 19% in 2012.[166] Granted this is a fall from 23% in 2000, however the decline in greenhouse gas emissions has been smaller in manufacturing than in other sectors (e.g. mining and quarrying).[167] In Germany the manufacturing sector is responsible for 15% of all CO2 emissions – slightly below the EU average despite its size (contributing 25% to the Gross National Product). German manufacturing industry consumes 29% of energy.[168]

The vision for Industry 4.0 is that everything will be networked through CPSs – 'people, things, processes, services and data'.[169] Production under Industry 4.0 will be more flexible and faster. Data might be available to all involved in real time. Increased interconnected data should bring efficiency gains and improved productivity, as resources are used as effectively as possible. This ultimately – to an undefined extent – should lead to improved sustainability.[170]

There is currently a substantial lack of evidence on Industry 4.0 and sustainability. One of the research tasks of the Potsdam Institute for Advanced Sustainability Studies on

---

[166] Eurostat statistics explained: Greenhouse gas emissions by industries and households. See http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emissions_by_industries_and_households

[167] Eurostat statistics explained: Greenhouse gas emissions by industries and households. See http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emissions_by_industries_and_households

[168] IASS Potsdam Institute for Advanced Sustainability Studies e.V. Sustainability Impacts of Industry 4.0. See http://www.iass-potsdam.de/en/research-clusters/enabling-technologies-sustainability/sustainable-ict-solutions/sustainable

[169] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung

[170] Buhr (2015) Social Innovation Policy for Industry 4.0. The Friedrich-Ebert-Stiftung

sustainability and Industry 4.0 (mentioned in research 5.1.6) is to try to find ways to assess the longer-term sustainability of Industry 4.0 within its current imprecise definition.

Risks that endanger the long-term prospects for Industry 4.0

Industry 4.0 is a long term programme, and it is envisaged that it will only become fully implemented from about 2025 onwards. There are risks to it actually taking off, as well as its continuation. As regards taking off, a great many preconditions are required to be met, including a robust technological infrastructure, people to design and work systems with the required levels of security, and people who have the vision to develop new ways of working between businesses and those with the skills and orientation to implementing such ways of working. In addition there is the concern that others may do this as well as, or better than, or more cheaply than EU entreprises. These are all significant risks that should be considered by both public policy makers and enterprises when embarking on Industry 4.0 initiatives.

5.3.3 The supply chain and SME participation

The evidence examined for this report indicates that there are large manufacturing firms in Europe that are in the process of implementing Industry 4.0 – type initiatives in their organisation and supply chains. Some SMEs in the European manufacturing sector are highly integrated in complex value chains as they supply large, multinational firms with parts as well as other products and services. Others supply local and regional networks.

Due to the interdependence of large manufacturers and their SMEs supply chains, there is a need for those SMEs to follow suit and adopt those advanced manufacturing technologies and ways of working. Those SMEs will have to adapt to new standards and methods in the sector in order to remain competitive and to remain linked into existing value chains and production networks. If certain big companies exploit their first-mover advantage to set industry standards, they may be able to compel SMEs to adopt these standards. Besides these external incentives, the expected improvements in productivity, enhanced innovation capability, and the modern image Industry 4.0 may convey are strong drivers for SMEs to engage with Industry 4.0.

This raises the question as to how SMEs can utilise the benefits of Industry 4.0 and ensure they are not left behind by larger firms. The Roland Berger study[171] sees the prospect for SMEs rather optimistically: a blurring between information and physical worlds along with a new focus on mobile manufacturing units and open production sites (smaller than present-day plants) and 3D printing may lower entry barriers for SMEs. Equally, as value chains become increasingly fragmented there are more entry points for new-comers, for example with regard to design, processing, handling customer data, etc., and more generally new ways of creating value and novel business models. The German working group mentioned earlier in this report also believes that Industry 4.0 will provide start-ups and small businesses with the opportunity to develop and provide downstream services and to thus integrate themselves into new value chains.[172] In reality, some will want to and be able to do that, others won't (see 5.1.2 and 5.2.1).

Beyond these potential benefits for SMEs, there are some changes to the business paradigm that SMEs face that may not necessarily be viewed as entirely positive: product portfolio aspects, financing considerations, customer relations will all be affected, as will the operational and strategic independence of the enterprise, posing new challenges to SMEs.

---

171 Roland Berger. 2014. Industry 4.0. The new industrial revolution. How Europe will succeed.

172 Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0 Final report of the Industrie 4.0 Working Group. 2013.

SMEs face some major challenges as regards the take-up of digital technologies in their operations. This is illustrated by a survey carried out in Germany in 2014[173], arguably one of the Member States with relatively more innovative and advanced SMEs. Based on a sample of 1,000 enterprises with a turnover between € 500,000 and € 125m, 35% of SMEs state that digital technologies play no major role for them. For the smaller companies in the sample, the respective share was 52%. For the future, 28% still believed that such technologies would not play a major role for them. On the other hand, for 49% of respondents, digitalisation is part of their business strategy. Activities aimed at monitoring the adoption digital technologies used by 21-25% of companies surveyed include using key performance indicators, benchmarking and exchange in chambers of commerce and industry associations. The expected benefits cited most often in the survey are: cost savings due to more efficient processes; enhanced competitiveness through intelligent production systems and networked processes; customised products and services, innovation through more flexible production; new sales channels; a more extensive market; and, customer analysis through the use of Big Data.

This list shows that some of the benefits generally associated with Industry 4.0 may also be reaped by SMEs. Interestingly, the identification of new lead markets was mentioned least frequently by survey respondents, perhaps demonstrating their dependence on larger multinational firms to realise such benefits.

The risks most commonly mentioned by survey respondents were: data security and the costs of investments required to ensure it; stability of technical infrastructure and vulnerability of it systems; increased competition; higher investment requirements; and, difficulty of recruiting skilled IT staff.

While these challenges apply to companies seeking to participate in Industry 4.0 in general, at least the last two points may be particularly relevant for SMEs. Importantly, at present, only 47% of staff in the companies surveyed was considered qualified to use digital technologies by responding managers. While the adoption of digital technologies is somewhat more general than the specific move to Industry 4.0, the survey findings nevertheless are relevant for the latter. Moreover, if the survey demonstrates that medium-sized enterprises in Germany often do not yet prioritise digital technologies, and, if they do, face many challenges, then this is probably even more the case in Europe overall.

The relative importance of SMEs to the economy as a whole, and of manufacturing SMEs to employment varies considerably between EU Member States. This has implications for the capability of different Member States to adopt and benefit from Industry 4.0 because, arguably, micro and small enterprises are less capable than medium or large enterprises to adopt Industry 4.0 technologies. Thus, it is important to look at the relative importance of micro, small, and medium manufacturing enterprises in the 28 EU Member States.

SMEs play a much more important role in terms of employment in some Member States, most notably the Czech Republic, Greece, Italy, Latvia and Poland, than in others.[174] Large manufacturing firms employ particularly many people in Germany, Finland and Sweden. This is also important against the background that in 2010, the labour productivity expressed in € per head in manufacturing in Europe was 73,000 in large enterprises as opposed to 39,300 in SMEs, i.e. manufacturing workers employed by large enterprises were 86% more productive than their counterparts in SMEs.

173 https://www.dzbank.de/content/dam/dzbank_de/de/library/presselibrary/pdf_dokumente/DZ_Bank_Digitalisierung_Grafiken.pdf

174 Eurostat, SBS_NACE_REV._2_C - Table 6a: Number of persons employed by enterprise size class, manufacturing (NACE Section C), 2010

Large manufacturing enterprises account for more than 50% of total value added in the majority of Member States.[175] Only in Cyprus, Greece, Italy and Latvia there is a clear dominance of SMEs, showing once again that the potential for SMEs to join in the Industry 4.0 transformation is greater in some Member States than in others.

As has been pointed out in a report by Gimélec, it may not be a proposition for a small or micro firm to link into Industry 4.0 if there is not sufficient scale or added value generated to make the up-front investment worthwhile.[176] We have not identified any research dealing with this specific question. Given the preponderance of small and micro enterprises in the EU, this is an issue of some importance.

These differences notwithstanding, SMEs face similar obstacles to participation in the supply chain of Industry 4.0:

- Lack of awareness about advanced technologies and the potential benefits of applying them in production processes;
- Ability to buy required technology and invest sufficiently in research and development where technology is not readily available – this, in turn, requires easy and swift access to finance;
- Capacity to run pilot projects to test out Industry 4.0 mechanisms and potentially limited access to facilities to test advanced solutions;
- Availability of highly skilled specialised (IT) staff needed to integrate and use advanced machine tools and the ability of SMEs to attract such skilled labour;
- Big companies may take advantage of their market position to first test and then patent new technologies – raising entry barriers for followers;
- Industry 4.0 may make internationalisation of production more pertinent than ever – this will be easier to execute for big corporations than for SMEs which in turn may increase the dependency of SMEs on bigger firms as their customers.

It has been argued that these obstacles can be overcome by adopting a multi-pronged strategy:

- By integrating into existing supply chains with Industry 4.0 'champions' and benefitting from their know-how;
- By focussing on developing niches within a more dispersed production system and marketing these in more localities internationally; and
- By embracing technologies such as 3d printing which make it easier to produce on a more decentralised basis.

Moreover, it will be key for SMEs to make use of data they already collect in their enterprise resource planning and customer relationship management databases but do not fully utilise yet. However, the extent to which such initiatives can be adopted by SMEs is questionable.

The role of the public sector (at national and EU level) in lowering entry barriers for SMEs to the Industry 4.0 market and supply chains

The public sector – both at EU and national level – can play a vital role to ensure that Industry 4.0 becomes a success. A study commissioned by the German Ministry of

[175] Eurostat, SBS_NACE_Rev._2_C - Table 6b: Value added by enterprise size class, manufacturing (NACE Section C), 2010

[176] Gimélec (September 2013); Industrie 4.0 L'usine connectée, p.13

Economy[177] recommended bringing together, processing and explaining the latest research to SMEs so that they can make use of it. In addition, SMEs need assistance in terms of advice and qualification.[178]

Public investment in R&D may offset private investment by corporations and thus contribute to a level playing field. An expert workshop organised by the European Commission in February 2015[179] that sought to identify SME readiness factors for adopting advanced manufacturing developed some concrete policy actions and tailored initiatives that could be implemented under the EU funding instruments COSME and H2020 in 2016-17 to make sure that SMEs are not left behind in the transformation to Industry 4.0. The EU could also create a portal listing all existing schemes that could support transformation to Industry 4.0 in order to make it easier for SMEs to apply for funding. In terms of addressing skills needs, vocational training on advanced manufacturing technologies could be funded by the European Social Fund. The expectation at the workshop was that such EU support to SMEs may induce Member State governments to follow suit with similar support schemes in their own countries. Potential supportive measures identified range from providing customised services to SMEs, promoting technology transfer, to facilitating interaction with research organisations at regional and local level. The latter points to the importance of adopting an integrated approach bringing stakeholders such as manufacturing advisory services, competence centres, research organisations, innovation intermediaries, and financial actors into contact with SMEs. This – according to the workshop findings – may help create a support ecosystem for manufacturing SMEs. On a more practical level, channels such as trade associations, trade shows and ties to regional/local technological institutes could be used to foster the understanding about and openness towards the uptake of new technologies in manufacturing.

There are some initiatives at EU and Member State level aimed at supporting manufacturing SMEs in the adoption of digital technologies such as I4MS (see Annex B) which could be built on by launching and promoting further pilot projects demonstrating the feasibility and utility of Industry 4.0 innovations as many SMEs maybe hesitant to adopt new technologies otherwise. A wide range of digital manufacturing initiatives is currently under way at EU and regional level (see Annex B).

More details about these EU and regional – level initiatives are provided in Annex B. In addition, under Horizon 2020 there are programmes in the relevant technology areas, and individual research institutions throughout the EU are carrying out research into the various aspects of Industry 4.0.

There should certainly be some *good practice examples* and lessons learnt from within the range of EU, national and regional initiatives identified. However, the study team has as yet not been able to identify a relevant document that pulls these together, nor have we been able to identify any evaluations of the initiatives in question. While some practices may be very specific to what can be achieved in some regions – for example within a leading cluster, others may be more widely applicable to more situations. It really depends on the practice in question. Some examples could be:

[177] Studie Erschließen der Potenziale der Anwendung von ‚Industrie 4.0' im Mittelstand. 2015. P. 38 & 164f.
[178] Studie Erschließen der Potenziale der Anwendung von ‚Industrie 4.0' im Mittelstand. 2015. P. 38 & 164f.
[179] http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8038

Table 5.1: Digital manufacturing initiatives[180]

Digital manufacturing initiatives	
EU - level	**Member State and Regional - level**
Application PPPs: FoF, SPIRE I4MS Smart Anything Everywhere ICT PPPs Vanguard (a multi-region initiative)	Austria: Produktion der Zukunft[181], [182], [183] Belgium: Made Different[184] Denmark: MADE[185] Finland: FIMEC PPP Programmes (MANU, S-STEP, S4Fleet), Industrial Internet Business Revolution, and IoT Pilot Factory[186], [187] France: Usine du Futur[188] Germany: Industrie 4.0, Smart Service World and Autonomik for Industrie 4.0[189], Italy: Fabbrica Intelligente[190] Netherlands: Smart Industry[191] Poland: INNOMOTO, INNOLOT Portugal: Produtech[192] Spain: Estrategia Fabricacion Avanzada[193] Sweden: Produktion 2030[194] United Kingdom: High Value Manufacturing, Innovate UK[195]

- In Sweden: At the Royal Technical College of Stockholm, XPRES (Excellence in Production Research) is a project in cooperation with the industry players Scania,

---

180 http://road4fame.eu/wp-content/uploads/2015/07/Member-States-and-Regional-Initiatives.pdf
181 http://www.ffg.at/produktion;
182 http://www.feei.at/feei-netzwerk/industrie-40-oesterreich-die-plattform-fuer-intelligente-produktion
183 http://wirtschaftsblatt.at/home/nachrichten/oesterreich/4763251/Osterreichische-Betriebe-investieren-in-Industrie-40
184 www.madedifferent.be; http://www.iminds.be/
185 http://www.made.dk/
186 https://www.fimecc.com/content/manu-future-digital-manufacturing-technologies-and-systems https://www.tekes.fi/en/programmes-and-services/tekes-programmes/industrial-internet--business-revolution/
187 http://de.slideshare.net/elehja/finnsih-view-regarding-industrial-internet
188 http://www.economie.gouv.fr/nouvelle-france-industrielle http://www.pole-astech.org/site/pages/index.php?doi=859b53568eb0059f7e6cbda05d35a77d
189 http://www.innovation-beratung-foerderung.de/INNO/Navigation/DE/go-Inno/go-effizient/go-effizient.html https://www.bmbf.de/files/Umsetzungsempfehlungen_Industrie4_0.pdf http://www.bmbf.de/en/19955.php http://www.bmwi.de/DE/Themen/Digitale-Welt/Digitale-Technologien/internet-der-dinge.html http://autonomik40.de; http://www.its-owl.de
190 http://www.fabbricaintelligente.it/; http://www.afil.it
191 http://www.smartindustry.nl
192 http://mobilizadores.produtech.org/en; http://portal.produtech.org/
193 http://www.spri.eus/es/actualidad-spri/noticias/innovacion-basque-industry-4-0-celebrara-su-segunda-edicion-el-14-de-octubre-en-bilbao http://www.eleconomista.es/economia/noticias/6872094/07/15/Industria-presentara-la-semana-que-viene-un-plan-para-impulsar-la-industria-40.html#.Kku81tPlwi3BrL7 http://www.europapress.es/economia/noticia-gobierno-preve-presentar-pocos-dias-agenda-impulsar-industria-40-20150713110502.html
194 http://www.produktion2030.se/ http://www.handelskammer.se/de/news/industrie-40-schwedens-industrie-baut-auf-die-technik-von-morgen
195 https://www.gov.uk/government/organisations/innovate-uk; https://hvm.catapult.org.uk/

Volvo CE, Sandvik, ABB, and Saab which focuses on creating smart and sustainable production solutions. One output will be LISA2, containing user-friendly app-like features that would allow SMEs to make use of smart technology as well.

- In the UK: in Wales, the EU funded project ASTUTE (Advanced Sustainable Manufacturing Technologies) ran from 2007-2013196. It supported 250 Welsh manufacturing enterprises through provision of resources, facilities, advice and guidance in collaboration with research facilities. The aim was to improve processes, accelerate research and development, improve growth prospects and facilitate new product developments.
- In Germany it is a goal of government to strengthen the innovation power of entrepreneurs and SMEs in the context of Industry 4.0.[197] For example, up to five competence centres are established funded with € 28 m over 3 years to help SMEs with application of Industry 4.0 by informing and advising them, creating awareness and supporting them using specific demonstration and testing tools to be displayed at the competence centres. By involving relevant trade unions, business associations, chambers of commerce, IT consultancies and other organisations the project maximises its participation, effectiveness and dissemination. Projects can cover a range of activities, including developing technological, organisational and work planning competences, improving competitiveness by creating new business activities, and by linking suppliers of Industry 4.0 technology and hesitant SMEs.

The European Commission has in the past commissioned research on good practices in specific subjects.[198] Such studies could make a useful contribution. In addition there are discussion fora, conferences and workshops to highlight the criticality of the issues concerned and provide a forum for exchange of knowledge and basis for future development could be organised.

5.3.4 Standardisation

Standardisation refers to the industry-wide adoption of standards, ultimately in the form of a coherent reference architecture or system that facilitates the interoperability of companies' production systems across countries and enables the full roll-out of Industry 4.0 in the global economy. Standardisation has been a critical requirement for the development of new industries in the past. Oftentimes, several standards and systems initially competed until one became dominant and was then widely adopted (e.g. mobile telephony). In the case of Industry 4.0, standards could apply to labelling and certification of IT interfaces (hardware, data formats, web services), programming platforms and control software, protocols, and connections, data transfer and security procedures. A reference architecture to provide a technical description of these standards and facilitate their implementation to help business implement Industry 4.0 is part of this process.[199] This will not work without a degree of openness and collaboration between companies.[200]

---

[196] http://www.astutewales.com/en/

[197] http://www.bmwi.de/DE/Presse/pressemitteilungen,did=717058.html

[198] See for example: Centre for Strategy and Evaluation Services (2013); *Evaluation and Exchange of Good Practices for the Sustainable Supply of Raw Materials within* the EU (DG ENTR) and Centre for Strategy and Evaluation Services (2013); *Evaluation and Exchange of Good Practices in the Tourism Sector to Stimulate Growth and Jobs in the EU.*

[199] Roland Berger Strategy Consultants, *Industry 4.0. The new industrial revolution. How Europe will succeed*, March 2014. p. 7
Forschungsunion/acatech. 2013. Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative. industrie 4.0. Final report of the Industrie 4.0 Working Group.

[200] Dr Werner Struth, Bosch, at: Sam Shead, *Industry 4.0: the next industrial revolution*, 11 July 2013

A basic step towards standardisation will be to agree on a common approach and terminology. There are already several established standards in use. However a coordinated overview of standards is lacking. Research is required to develop a working overview of existing standards in fields such as industrial communication, engineering, modelling, IT security, device integration, digital factories, to be integrated into a new global reference architecture used by Industry 4.0.

The Industrie 4.0 Working Group outlines how standardisation could unfold[201]: By building a reference architecture, stakeholders should focus on integrating a range of dimensions and aspects, including: the manufacturing process; specific networked devices within manufacturing systems such as controllers, operating devices and workstations; software applications including ways to process and analyse data, and for logistics and business management; and, engineering perspective and product lifecycle management

As mentioned in section 3.2, a survey carried out in Germany in 2013[202] identified standardisation as the most important challenge in implementing Industry 4.0. Several reports[203] reviewed for this study confirm this finding. In absence of common standards, manufacturing companies will find it difficult to create inter-company value networks.[204] The full potential of Industry 4.0 can only be realised through global networking of production and globally functioning applications, which in turn is impossible without uniform standards.[205] Standards would have to be open, reliable and secure in order to find acceptance and be widely adopted. Standardisation is a challenge with regard to safety too. At present the industry lacks fully standardised safety and security solutions. Without common standards, production systems would remain incompatible globally and Industry 4.0 would be restricted to local production, limiting tis capacity to realise economies of scale and to account for dramatic gains in productivity. In particular, “Smaller companies are looking more for precast solutions and proven standards,” said SAP's Christoph Behrendt. Many such firms “still do not have a plan for the transition”.[206]

The role of policy

Policy makers should support the introduction of relevant international standards both at national level and globally. Most likely, Industry 4.0 standards would be adopted incrementally and a top-down approach may not work. Nevertheless, standards developed, for example, in course of specific projects, should eventually be converted into international standards. This is where policy makers can play a constructive role. One way would be to support and encourage open source initiatives that also helped in setting standards for the Internet such as the Internet protocol TCP/IP.[207] Policy makers should organise workshops and conferences where potential and emerging standard-setters from industry, research, and beyond can sit together and discuss a way forward. Where standards will be set by individual companies, policy makers should support and facilitate the development of licensing models allowing other companies and new entrants to adopt these standards and integrate in existing value chains. The German Industrie 4.0 Working Group, to this end,

---

[201] Forschungsunion/acatech. 2013. Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative. industrie 4.0. Final report of the Industrie 4.0 Working Group. P. 39

[202] Source: BITKOM, VDMA, ZVEI 2013. Found at: Forschungsunion/acatech, *Securing the future of German manufacturing industry Recommendations for implementing the strategic initiative INDUSTRIE 4.0*, 2013, p. 25

[203] Deloitte (2014) Industry 4.0 Challenges and solutions for the digital transformation and use of exponential technologies

[204] Forschungsunion/acatech. 2013. Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative. industrie 4.0. Final report of the Industrie 4.0 Working Group. P. 39

[205] Germany Trade & Invest. Industrie 4.0. Smart Manufacturing for the Future. P. 21

[206] http://www.euractiv.com/sections/innovation-industry/smes-largely-wary-digitalisation-germany-315453

[207] Forschungsunion/acatech. 2013. Securing the future of German manufacturing industry. Recommendations for implementing the strategic initiative. industrie 4.0. Final report of the Industrie 4.0 Working Group. P. 41

recommends establishing a dedicated Working Group on standardisation. This Working Group, which has since been set up, focuses on the following activities:

- Bringing professional associations and other stakeholders together to build mutual confidence in establishing common standards
- Alignment of key terminology and production of a "Industrie 4.0 glossary"
- Develop standards for service architecture, procedural and functional descriptions, terminology standards, understanding of autonomous and self-organising systems, system structure description, etc.
- Production of a bottom-up map outlining existing standardisation bodies and approaches relevant for Industry 4.0
- Develop top-down roadmap open to stakeholder input
- Help build an Industry 4.0 community that continue to work on standards and a reference architecture

Overall, this is a major issue, given the huge business interests in question, involving companies world-wide. A recent press release indicated that the community in charge of Industry 4.0 announced its choice for a standard for communication between machines - OPC UA – which appears in the reference architecture for the consortium (RAMI 4.0 - Reference Architectural Model Industry 4.0).[208] The article suggests that this standard, while well-known and used in Germany and the USA is very little employed in France.

5.3.5 Limitations to the export of Industry 4.0 equipment and services

One of the key advantages sought after from an EU point of view from implementing Industry 4.0 is to maintain and increase the strength of the EU manufacturing industry's international competitiveness. This is expressed in more success in export markets. The question then arises as to how those products can be protected from being copied. There are certainly IP protection issues at stake in many of the fast growing target markets for such equipment in third countries. Recently there was a visit by the German economy and energy minister to China to discuss collaboration on Industry 4.0 and IP was one of the points discussed. However, as indicated in Case Study 5 on developments in China, demand is growing very strongly there and there are many Chinese companies active in the field. It is not clear how it will be possible to police or enforce IP protection in such a market. This is true of the other BRIC and emerging markets as well.

Nor is it apparent that there is anything to stop EU-based multinationals from manufacturing and supplying markets in third countries where they have such facilities using technologies and business models developed in the EU. Such business decisions are usually driven by the nature of the markets in question and the strategic technology capabilities available in the market. This has been happening on other sectors ranging from automotive to electronics and pharmaceuticals for some decades now – there is no reason why it will stop in the case of Industry 4.0 products. In fact, if there is a large supply of STEM graduates working for substantially lower salaries than those in the EU it would be a rational business decision to set up supply operations in such a location with low costs and a large and growing market.

As indicated in the discussion relating to standards, international standards could be a significant barrier to the diffusion of Industry 4.0. In addition, as the foschungsunion/ acatech report points out, with increasingly complex systems being deployed in Industrie

[208] http://www.usine-digitale.fr/article/industrie-du-futur-la-guerre-des-standards-a-commence.N334563, Frederic Parisot

4.0, it becomes increasingly likely that individual components may be subject to national and international trade restrictions.

Encryption technologies are both necessary and desired by customers to ensure the confidentiality and integrity of CPS communication, but in many emerging markets such as China, the use, sale, importing and exporting of encryption products are only permitted under licence. This may undermine the validity of the protection in question. Already, companies wishing to have a global presence in tomorrow's key markets are to some extent finding themselves forced to operate in legal grey areas if cryptographic components are built into larger manufacturing facilities. This legal uncertainty will only increase in Industrie 4.0 and could become a significant barrier to trade.[209]

In the EU, on the other hand, shipment of encryption technologies is allowed within Europe and to certain other countries such as Japan, Canada and the US, but they are classed as dual use goods11 and subject to export restrictions for many other destinations.

The appropriate fora through which to deal with such issues would be the WTO, and the WIPO. As regards developing international standards, this should be done in collaboration between the public and private sector organisations involved.

5.3.6 Industry 4.0, the EU's global competitiveness and domestic manufacturing industry

Competitiveness is directly linked to gains in productivity which in turn depends to a large extent on investments in innovation. EU research and development intensity is lower than in the US and Japan. Likewise, developments in the information and biology technology industries began later in the EU than in the US and Japan[210]. Consequently, various indicators point to a decline in the competitiveness of European industry in recent decades. Since 1995, productivity growth in European manufacturing has been slowing and lagging behind the USA. EU industries are also increasingly competing with emerging economies such as China and India. This now applies also to industries in which the EU has been traditionally strong, such as the chemical industry, mechanical engineering and motor vehicles – industries characterised by medium-high technology and medium-low skills.

European industry has in recent decades seen its share of world markets decline as many industrial activities where moved offshore and emerging countries – China in particular – caught up. Indeed, the share of world production of emerging economies doubled in the last two decades and now amounts to 40% (€ 6,577 bn in 2013).[211] At the same time, Europe has experienced widespread deindustrialisation: the number of industrial jobs since 1991 has decreased by 8% in Germany, by 20% in France and by 29% in the UK.[212]

As shown in chart 2.5 the trend varies significantly between EU Member States: while the manufacturing value added as a percentage of total value added in the German economy remained constant from 2001-2011, it went down from 15% to 11% in France and the UK and from 17% to 14% in Spain.[213] In the EU overall, manufacturing's contribution to GDP shrank to 15.1% in 2013.[214]

---

[209] Forschungsunion/ acatech, op.cit., p.60

[210] Y Sun, *Industrial Policy of the EU: Development and Recent Progress*, Working Paper Series on European Studies, Institute of European Studies, Chinese Academy of Social Sciences, Vol. 1, No. 8, 2007

[211] Roland Berger Strategy Consultants, *Industry 4.0. The new industrial revolution. How Europe will succeed*, March 2014. p. 2

[212] Roland Berger Strategy Consultants, *Industry 4.0. The new industrial revolution. How Europe will succeed*, March 2014. p. 3

[213] Source: UNCTAD, at: Roland Berger Strategy Consultants, *Industry 4.0. The new industrial revolution. How Europe will succeed*, March 2014. p. 6

[214] European Commission, *Member States' Competitiveness Performance and Implementation of EU Industrial Policy report*, SWD(2013) 346, 2013

On the other hand, the EU Competitiveness Report 2014[215] cautions that the perceived decline of European industry as expressed in terms of share of GDP is partly due to productivity gains and associated falling relative prices of manufacturing in relation to services. This may well explain the difficulty in reaching the 20% reindustrialisation target set by the European Commission but also puts into question the appropriateness of such a target given that manufacturing industry is increasing its productivity.

One explanation given for these trends is that the competitiveness of Europe's industry and SMEs in particular is still suffering from the financial crisis.[216] Moreover, high energy prices have had a negative impact on industrial competitiveness, despite the energy-efficiency of European manufacturing in some sectors. Other reasons cited include demographic change which brings about an ageing population and a shrinking workforce as well as rising labour costs rising in absolute terms and relative to emerging economies. Other potential factors which may have a negative impact on competitiveness are certain types of regulation and taxation, a lack of innovation finance, slow adoption of new technologies, inefficient use of resources, and a mismatch between skills required and skills available in the labour force.

These issues notwithstanding, European industry remains competitive at the global stage.[217] This is especially relevant for sectors characterised by high technology intensity, such as pharmaceutical products, and by medium-high technology intensity, such as chemical products, machinery and equipment, motor vehicles and other transport equipment. Moreover, the EU has great advantages in chemical products, machinery and transport equipment, but also in metal products, wood and wood products, paper, printing and recorded media.[218]

Industry 4.0 and EU competitiveness

A major theme that has emerged from this study is the heterogeneity of the manufacturing industries of the EU's Member States, even if there are pan-European and global value chains present. So while Industry 4.0 can play a role in changing the dynamics of competitiveness, how this happens will vary at EU Member State level. The most obvious contrast is between Germany and Italy, the countries at first and second position in terms of the size of their manufacturing industries (see chart 2.3). In the case of Germany this would be a competitive advantage developing strategy, working on the policy frontier (see chart 2.1). In the case of Italy, it is not clear to the study team how Industry 4.0 would fit with the overall industrial structure, given the high level of small and micro enterprises. Looking at the "Industry 4.0 Readiness" scale of Roland Berger, the countries that are "front runners" other than Germany are, Sweden, Austria and Ireland. The latter three countries all register their shares of EU industry at the <4% level, so it is unlikely that these countries alone will turn around trends at EU-level competitiveness. For Industry 4.0 to lift the EU-level of industrial competitiveness will require transformation in some of the other larger countries (e.g. Italy, France, the UK, Spain, The Netherlands) and smaller economies. Implementing change at that level would require sustained effort and commitment over many years, maybe even decades, and there are many preconditions for success to be met. This does not imply that Industry 4.0 initiatives should be abandoned, just that the expectations in terms of outcomes need to be realistic. The outcomes throughout the EU-28 will be uneven. It is still be essential to develop and continue with initiatives along the lines of Industry 4.0 as this is a direction that a significant share of global manufacturing is moving towards.

[215] European Commission, *Helping Firms Grow. European Competitiveness Report 2014*, 2014
[216] European Commission, *Helping Firms Grow. European Competitiveness Report 2014*, 2014
[217] European Commission, *Helping Firms Grow. European Competitiveness Report 2014*, 2014. p. 11
[218] European Commission, *Helping Firms Grow. European Competitiveness Report 2014*, 2014. p. 12

From an EU point of view, Industry 4.0 can be part of both a defensive and a pro-active strategy: defensive in that it could help Europe to preserve its domestic manufacturing industry and pro-active in that it could help Europe to increase its global competitiveness and access new markets. For example, the labour shortage due to demographic change could be (partially) offset through automation and the increased productivity of machines, reducing the need to rely on manual labour. Due to its overall skilled workforce Europe seems well-placed to benefit from Industry 4.0. However, as noted in 5.2, there are already shortages in skilled labour that have to be met from outside the EU. Many emerging economies now also include young and technology-savvy workforces and global multinationals that will compete with the EY.

Industry 4.0 is expected to increase productivity overall through efficiency gains. These can be realised, for example, by achieving just-in time maintenance and gaining near zero downtime. *Virtual industrialisation* will allow manufacturers to design and test new plants or factories in detail in the digital world before they are actually set up, which means that mistakes later on can be avoided[219]. Germany's National Academy of Science and Engineering argues that this could lead to a 30 per cent increase in industrial productivity.[220] Increased productivity reduces the cost per unit of production, which can compensate for higher labour costs compared to emerging economies. As a result, Industry 4.0 may allow the re-shoring of activities currently offshored to other countries such as China or prevent further offshoring in the future. Lower materials and energy consumption, increased operating precision, and improved pollution management may further increase competitiveness. However, it is not certain that this would be replicated throughout all the EU's economies.

The question then is how it can be ensured that high added value production and processes remain in Europe. A paper by the European Centre for International Political Economy (ECIPE)[221] provides some useful insights based on a review of industrial policies. According to their research, targeted industrial policy aimed at identifying successful industries and firms has largely failed. Rather, the EU should adopt (retain) a horizontal industrial policy, which promotes competition, encourages innovation, coordinates between types of various stakeholders and facilitates industrial change. Currently, the creative destruction process by which new firms replace old ones, and resources are shifted from slow-growing to fast-growing sectors – is slower in Europe than in the US.[222] Labour market reforms and a strengthened higher education system, according to ECIPE, would also facilitate change.[223] Education in particular is key as the success of Industry 4.0 in part depends on adequate skill-sets due to increased complexity even as many activities are taken over by machines.

In the US the move to Industry 4.0 is led more by the private sector than in Germany and in Europe (Case Study 4). The Industrial Internet Consortium was set up in 2014 by big companies such as General Electric, Cisco, Intel, and IBM to bring together business, academia and government entities to modernise sectors such as manufacturing, energy, transportation, healthcare, utilities, cities and agriculture with help of the Internet.[224] Reflecting its non-government nature, the initiative is rather open to inputs from outside the US, including from European technology companies and government organisations from

---

[219] Roland Berger Strategy Consultants, *Industry 4.0. The new industrial revolution. How Europe will succeed*, March 2014. P. 9

[220] Sam Shead, *Industry 4.0: the next industrial revolution*, 11 July 2013

[221] ECIPE / Geoffrey Owen, *Industrial Policy in Europe since the Second World War: What has been learnt?*, Occasional Paper 1/2012

[222] ECIPE / Geoffrey Owen, *Industrial Policy in Europe since the Second World War: What has been learnt?*, Occasional Paper 1/2012, p. 46

[223] David Encaoua, 'Nature of the European technology gap: creative destruction or industrial policy?' Dominique Foray (ed), *The new economics of technology policy*, Edward Elgar, 2009.

countries including China, India, and Germany. But in the US, too, government has played an important role: Recently the U.S. government co-founded a National Network for Manufacturing Innovation (NNMI) made up of several Institutes for Manufacturing Innovation. The significant developments in China, where rising wages have been a major driver for robotisation, are outlined in Case Study 5.

In what way could Industry 4.0 counteract such a trend? Would it not be enough to maintain a constant share? Or should the measure really be the market position of EU firms in the changing global economy? Certainly, it is critical for EU industry to maintain and increase its competitiveness, but this will not stem the advance of the BRIC economies, even a constant share of an increasing market is positive.

One development which might give an impetus to the move to Industry 4.0 might be the emergence of new "champions" – companies demonstrating the value of fully adopting Industry 4.0. Two main ways can be envisaged how companies can create or adapt business models based on Industry 4.0: There are – often well-established manufacturers – benefitting from adopting Industry 4.0 and thus improving their market share, and there are companies – often but not necessarily newcomers – actually producing and selling the technology and services required by other companies to adopt Industry 4.0. They may well sell those technologies to companies outside Europe as well, in which case there is of course, a risk that this will eventually undermine Europe's competitiveness as a whole if it helps other economies to catch up. Roland Berger suggest that mergers and acquisitions may be needed to create Industry 4.0 champions and that new industry associations would support the development. Rather than policy-makers trying to pick the future champions, they should take a pragmatic approach with regard to antitrust policy in order not to stifle the consolidation of industry and the emergence of new champions.

That it would be difficult to pick champions is confirmed by the ECIPE report[225] according to which such a top-down approach would not work as innovations in Industry 4.0 usually occur in a bottom-up manner.

[224] Bledowski, Krzystof. 2015. MAPI The Internet of Things: Industrie 4.0 vs. the Industrial Internet
[225] ECIPE / Geoffrey Owen, *Industrial Policy in Europe since the Second World War: What has been learnt?*, Occasional Paper 1/2012

6. CURRENT POLICIES

KEY FINDINGS

- There are several reasonable and acceptable grounds for intervention in industrial policy at EU and at Member State level.
- While a good deal is already occurring in terms of policy there are some gaps: policy is not always co-ordinated around the targeted aim of Industry 4.0 or the Industrial Internet 9as the case may be) – it is fragmented. Also, policy tends to focus on the technical research side, and may neglect human factors/ sociotechnical aspects (including labour supply) and preparing for new ways of doing business.

6.1 Rationale for intervention

The EP and the Commission have, as set out in 2.3 taken a range of steps to support manufacturing industry in Europe. In addition, as set out in section 5 there is a wide range of policy initiatives in the field of research, social and human resources and industry initiatives in existence supporting digital industry at EU, national and regional level. The individual Member State reviews in Annex B provides some further details.

There are several potential *rationales for policy intervention:*[226]

- Laissez faire – do not intervene
- Traditional state intervention – based on ownership of assets
- The neo-classical/ liberal approach aimed at "correcting" market forces
- New growth/ technological capability development
- Institutionalist neo-Schumpeterian evolutionary systems-based rationale

The review of policy in 2.3 suggests that the EU on the whole is tending towards the latter three orientations.

Within the neo-classical liberal model there are various grounds for intervention:

- The presence of externalities: positive externalities occur when benefits accrue to those not involved in a transaction. In the case of supporting manufacturing industry, a wide range of positive externalities can occur, including increased productivity and associated wage gains, employment, technological spin-offs, exports, and improved competitiveness for those not directly affected by the intervention.
- The existence of public goods and services: it may be impossible to exclude those benefiting from improvements in manufacturing productivity from such benefits. Hence a general intervention is justified.
- Asymmetric information problems: insufficient (or incorrect) information among participants can lead to inefficient markets and a wasteful allocation of resources. This means that people may be better off if these information gaps can be bridged. In this instance it may mean that many companies (e.g. SMEs) are still not aware of the challenges, opportunities and costs involved in CPS and the internet in manufacturing in the future, or what to do about it, or what support is available.

[226] Warwick, op. cit.

- Coordination problems: coordination problems may prevent market participants from overcoming the above-mentioned problems or their consequences. Market-driven initiatives to solve these may not be forthcoming. For example, at national state or European level there may be a need for a “platform” to co-ordinate initiatives related to the digitalisation of manufacturing, CPS and the internet (e.g. the Industrie 4.0 platform in Germany, and the equivalent in Austria), that acts as a centre for dealing with coordination between economic and political stakeholders. However, not all EU Member States have developed such policy tools and there may be scope for more to be done at EU level either in order to complement national initiatives or to ultimately bring them together under one umbrella.

The new growth and institutionalist models also provide a further rationale for intervention based on supporting new industries and adjusting to structural change in the economy.

6.2 EU level

In the context of the challenges and opportunities facing EU manufacturers, the EU adds value by supporting or funding research that individual companies or Member States might not carry out on their own, and providing pan-European platforms for pan-European research (e.g. through Horizon 2020) sharing information, experience and good practice.

A set out in section 5 (5.1.6 and 5.3.3) and Annex B there is already substantial activity under way at EU level, although we have not identified any evaluations of these initiatives as yet, nor any assessments as to whether the initiatives in question individually or as a group will be able to make a meaningful impact on EU manufacturing competitiveness as a whole. As some of these are now reaching a stage where they can be assessed, it is probably a good time to launch some such evaluations.

In principle, as mentioned in the previous sub-section, the EU can add value since there are Member States that may currently lack a coherent Industry 4.0 – type strategy that includes technical, social and business paradigm elements - or even a set of initiatives potentially building up to such a strategy or platform. There appears to be a good deal of emphasis on the purely technical aspects, possibly overlooking some of the human factors and business issues involved. Some Member States may lack the capacity to launch a strategy or platform themselves and will thus benefit from EU support to bring them up to speed. The EU could also help to streamline and consolidate existing measures in Member States, facilitate the exchange of best practices, and facilitate specialisation within the European economy. This would also help avoid unnecessary duplication and lead to leveraging of lessons learnt.

6.3 Member State level

Member State policies tend to reflect circumstances in the Member States in question – for example as regards the specific and different cases of the UK, France and Italy. They are following a mix of policies that they consider appropriate for their circumstances – whether comparative advantage leading/ following, catch-up/ frontier (see Chart 2.1).

However, given that, based on our research, a good share of Member States has not adopted policies at national level specifically addressing Industry 4.0 or Industrial Internet – type issues, there is a case for such Member States reviewing their positions in this respect, and the implications as regards research on manufacturing and employment (e.g. emigration of qualified workers to areas where there is a high demand for those with the required skills). Otherwise, they risk falling behind both in the European and eventually the global market.

6.4 Gaps in policy

In order to move towards implementing the vision underlying Industry 4.0 in practical terms, as set out in section 2.3 and 5, it requires co-ordination and planning on a pan-European scale that affects a very wide range of activities, including supporting research and pilot projects, developing legislation on standardisation and data issues, training of students at universities and people currently in work, organising immigration to address skill gaps, completing the digital single market, and enterprises designing and adapting to new business models, etc. While many Member States are carrying out these activities, Industry 4.0 as implemented in Germany is doing it in a very targeted, co-ordinated, and structured manner.

As such Industry 4.0 is certainly a comprehensive and ambitious approach that appears to be well-suited to the German situation. In some EU Member States, notably Austria, Belgium, Denmark, Finland, France, Italy, The Netherlands, Portugal, Spain, Sweden and the UK there is strong support and interest. But only in a few instances is the programme as comprehensive as in Germany.

In terms of “policy gaps” then it can be concluded that in many instances the gap lies in the absence of a comprehensive and co-ordinated plan. Different policies may be seen as fragmented.

However, not all EU Member States have the same degree of dependence on manufacturing that Germany does. Nor do they all have the same situation as regards availability of STEM-type employees (supply and demand), or have the same aspirations for their manufacturing industry. Hence, it is unrealistic to expect them to design and implement such comprehensive programmes as Industry 4.0, especially in an environment of fiscal constraint. In other words, what may be considered a “gap” in one country might not be one in another. But, given the fact that there are pan-European industry value chains, if a corporate network has subsidiaries or suppliers in a country that has a low share of industry and where industry is not prioritised to the same extent as in a high-share country, those plants and that Member State will be at a disadvantage that could, like compound interest, grow substantially in the longer term.

Also, there appears to be a tendency in some of the Industry 4.0 – type strategies and polices adopted developed to emphasise the technical aspect. This undervalues the significant changes that are expected from people – both managers and staff – to make Industry 4.0 work. There is a paradigm shift required both from employees and managers: the work to be done, and the design and management thereof. Even with training and education, it might end up being a challenge to meet the complex requirements in question in the required numbers.

In addition, it appears that the SME aspect, and in particular the micro and small firm aspect, has been glossed over (e.g. as regards minimum capital requirements, scale and scope, issues around independence and flexibility in selection of customers and suppliers). This has more pertinence in some Member States than others, but is a real concern.

Finally, it needs to be borne in mind that Industry 4.0 is focused on manufacturing. There is a much wider scope of digital activity in terms of sectors encompassed by the notion of the Industrial Internet as pursued in the USA and through the Industrial Internet Consortium (see Case Study 4).

7. ASSESSMENT

KEY FINDINGS

- Industry 4.0 presents many potential benefits for industrial development, but there are also important costs and risks. There will be winners and losers, and adjustments to make.
- The public sector has the responsibility of supporting and monitoring the process through the various instruments at its disposal as the process unfolds over the next 10-15 years.
- The history of industrial policy caveats against a too direct involvement in the process by the authorities.

7.1 Key benefits and drawbacks

The following table summarises the major strengths and weaknesses, opportunities and threats related to Industry 4.0

Table 7.1: Industry 4.0 – SWOT table

Strengths	**Weaknesses**
• Increased productivity, (resource) efficiency, (global) competitiveness, revenue • Growth in high-skilled and well-paid jobs • Improved customer satisfaction – new markets: increased product customisation and product variety • Production flexibility and control	• High dependence on resilience of technology and networks: small disruptions can have major impacts • Dependence on a range of success factors including standards, coherent framework, labour supply with appropriate skills, investment and R&D • Costs of development and implementation • Potential loss of control over enterprise • Semi-skilled unemployment • Need to import skilled labour and integrate immigrant communities
Opportunities • Strengthen Europe's position as a global leader in manufacturing (and other industries) • Develop new lead markets for products and services • Counteracting negative EU demographics • Lower entry barriers for some SMEs to participate in new markets, links to new supply chains	**Threats** • Cybersecurity, intellectual property, data privacy • Workers, SMEs, industries, and national economies lacking the awareness and/or means to adapt to Industry 4.0 and who will consequently fall behind • Vulnerability to and volatility of global value chains • Adoption of Industry 4.0 by foreign competitors neutralising EU initiatives

7.2 Business results and expected impacts – will it work?

The aim of Industry 4.0 is to ensure the competitive future of German (and EU) manufacturing industry through co-ordinated interventions on several fronts including research and development, education, skills and training, and changing of business models to suit a new manufacturing paradigm envisaged for the future. As made clear in section 2.3 and 5, a wide range of preconditions needs to be met in order to realise the aims of the initiative: technical, social/ employment and business. Many factors – some unforeseen at present - will influence whether it is successful over the next 10-15 years as the initiative takes shape and matures from the embryonic form it still has at present.

At this stage, it certainly appears that there is a case for launching most of the initiatives that have been identified under the heading of Industry 4.0. However, in reality, many of the elements still have to be designed – for example the education and skills development and assessment programmes for future Industry 4.0 employees – then the students have to go through the educational systems, and then get practical experience. It will be some time before it is apparent whether the educational element has been successful or not. Similarly, with the development of “new ways of doing business through “network-centric” approaches, while there may be some instances of that already present, but how long will it be before that is widespread and when it will be possible to assess the impacts? It may take years before such different ways of doing business are widely established. It will also be some years before it is possible to determine whether the goals of increased efficiency, lower design and operating costs, etc. have been realised, or how widespread that actually is throughout industry.

As indicated in section 2.6, a key question is how will it be evaluated it in three, five, ten, fifteen years’ time? What will be the indicators – qualitative and quantitative? Which results and expected impacts will be attributable to Industry 4.0? At this stage it is not clear from the documents reviewed that this has been spelled out.[227]

7.3 Where public sector support could add value

There are several areas where the public sector can add value. These are to:

- Assess countries’ positions vis à vis developments in the area of CPS, digital manufacturing and the internet.
- Where appropriate, put policies in place as regards, for example, education, migration, research in digital manufacturing, or institutions to support different ways of doing business.
- Raise awareness about the challenges and opportunities in the area of Industry 4.0 and the Industrial Internet.
- Provide fora and platforms for stakeholders to become involved, including the national chambers of industry, research institutions, etc.
- Collaborate with other countries on the subject – e.g. share best practices, develop joint initiatives (e.g. for specific sectors).
- Work with European institutions such as ERDF and ESF to identify and develop appropriate support possibilities.

[227] For the challenges in evaluation of industrial policy and tools to deal with them see: Final report of the Impact Evaluation Expert Working Group (2012); Dare to measure: Evaluation designs for industrial policy in The Netherlands.

Certainly there is no ground for complacency when for example considering developments in other parts of the world such as China, which is no longer positioning itself as a low-cost manufacturer (see Case Study 5), or South Korea.

7.4 The type of support

The review of policy experience (section 2) suggests that the support to be provided should be indirect, through signalling, signposting and leading, co-ordinating and creating an environment in which enterprises working in the field can flourish. Where possible, support can be provided through lead markets (e.g. procurement policy). The specific areas where preconditions have to be met for successful implementation of Industry 4.0 (and the Industrial Internet) have been identified in 3.2.2.

In this context, it is important that government consults with industry as regards for example designing educational and training programmes that may take a long time (4-6 years or more) to bear fruit. There are already a good many programmes under way for technical development that need to be assessed before it will be possible to consider if or how they have contributed. How SMEs can deal with the up-front as well as ongoing investments to participate in the Industry 4.0 arena also needs more consideration, especially in some Member States.

8. RECOMMENDATIONS

KEY FINDINGS

- The design and implementation of Industry 4.0 – type initiatives throughout the EU should continue and be supported
- However, policies need to be developed that are appropriate for the economic conditions in specific Member States – a copy and paste approach will not work.
- Existing policies need to be evaluated and refined before new approaches are designed and launched.

The study has found that what might be described as "the Industry 4.0 approach" has only begun to be implemented recently (e.g. Austria, Spain and France) and to different degrees in different Member States. So it will be some years before it will be possible to answer the question as to whether it has been implemented effectively or not, and whether it is producing the desired results and outcomes. However, from a conceptual point view it is integrated and thorough, addressing the main areas in question in a holistic manner. Whether this will be enough to deal with the many issues, such as security, standards, adoption by SMEs, labour force requirements and managerial challenges in order to realise the outcomes envisaged remains to be seen.

It is also clear that there are already EU as well as Member State and regional-level initiatives in existence dealing with the issues involved in researching, designing, developing and implementing changes in manufacturing industry related to digitisation, CPS and the internet. However, it does appear that initiatives tend to focus on technology or R&D, or manufacturing, or the role of the internet. They are often somewhat piecemeal, and a holistic, integrated framework that includes staffing and business paradigms is not always adopted. Such an approach may reflect the strategy of the country in question, reflecting its own economic realities.

So while the study makes recommendations as set out below, this is done with the proviso that before any significant new policies are implemented or existing ones refined at EU, Member State or regional level, there is a need to carry out a more detailed evaluation (rationale, effectiveness, efficiency, coherence and sustainability) of what is already under way at EU and Member State (also regional) level.

8.1 Refined policies

When Member States review and evaluate their existing policies in the areas covered by Industry 4.0, the study suggests that a wide approach, including social change and development in business paradigms should also be brought into the equation. Hence it would be useful to pay detailed attention to the specific areas covered within the scope of Industry 4.0 to be assessed e.g. skills, migration (intra-EU and from Third Countries), business organisation (ways of collaboration and sharing risk, information), cross-border collaboration programmes for enterprises, cybersecurity and standards, and implications for SMEs.

Many of these issues have a cross-border and even pan-European element, e.g. migration of skilled labour, completing the digital single market and cybersecurity, cross-border research, standards etc. There might also be impacts on the EU's economic geography that have ERDF and ESF implications. Therefore, in the process of reviewing and refining policy there is considerable scope for EU-level involvement.

8.2 New policies

There is scope for more policy activity at EU – level and in many Member States in terms of the areas identified in 7.2 above, very much aimed at developing more holistic and integrated responses, rather than what comes across at present as a somewhat fragmented approach, by:

- Assessing countries' positions and needs both within the EU and globally vis a vis the developments in the area of CPS, digital manufacturing and the internet.
- Where appropriate, putting in place policies and supporting funding as regards, for example, developing pilots, education, migration or research in digital manufacturing.
- Making funding available and introducing supporting measures targeting SMEs to ensure these can participate in the developments around CPS, digital manufacturing and the internet and integrate into emerging value and chains and production networks. This includes awareness-raising, improving access to finance, supporting regional clusters and partnerships.
- Raising awareness about the challenges and opportunities in the area of Industry 4.0 and the Industrial Internet. Helping identify and develop lead markets for Industry 4.0 products and services.
- Supporting development of a framework conducive to the swift adoption of standards in this newly emerging sector whilst safeguarding data protection and IT security.
- Provision of fora and platforms for stakeholders to become involved and exchange best practices, including the chambers of industry, research institutions, etc.
- Collaboration with other countries on the subject – e.g. sharing best practices, developing joint initiatives (e.g. for specific sectors).
- Working with European institutions such as ERDF and ESF and within the Horizon 2020 framework to identify appropriate support possibilities.

APPENDIX A: CASE STUDIES

Case Study 1: An "Industry 4.0 Bill of Rights"?

In March 2011, the company 'Pachube' (after 2011 renamed Cosm having been acquired by LogMeIn; Cosm has subsequently been rebranded Xively) proposed an "Internet of Things Bill of Rights". The aim of this initiative was to establish a set of rights which could develop into an industry standard. The "Internet of Things Bill of Rights" consists of the following eight principles:

1. People own the data they (or their "things") create.
2. People own the data someone else creates about them.
3. People have the right to access data gathered from public space.
4. People have the right to access their data in full resolution in real-time.
5. People have the right to access their data in a standard format.
6. People have the right to delete or backup their data.
7. People have the right to use and share their data however they want.
8. People have the right to keep their data private.

As pointed out in section 3.1, the Internet of Things (IoT) is slightly different to but still part of the "family" of concepts to which Industry 4.0 belongs. The main idea of the Internet of Things (IoT) is that "everything should talk to everything else. These talkative "things" include sensors, consumer appliances, home automation systems, and even connected vehicles."[228] This indicates that IoT is mainly about the relationship between services/products and its customers. In this context, personal data is key since it can be regarded as 'fuel' for the operability and performance of the smart product. An often-quoted example in this context is the smart fridge which collects data on the eating habits of its owner. This data ensures its proper functioning (e.g. placing orders to supermarkets when the owner runs out of its everyday food). At the same time, however, it also creates a huge amount of sensitive data. For example, data on eating habits can reveal health status, religion, financial situation etc. This then feeds back also to the manufacturing company with information about temperature settings, number of times opened, performance of individual components, etc. Therefore, the Internet Bill of Rights is a reasonable and important step in an increasingly interlinked world.

This situation is slightly different in the Industry 4.0 context. Data generated in the Industry 4.0 context is mainly about the production chain and how to optimise the production. Since data is mainly generated for and through machines in the production process, concerns other than personal data seem to be a priority. So the first thought is about protection against industrial espionage, intellectual property and cyber criminality (e.g. malicious theft and use of data to create damage, as in the case of a steel company in Germany quoted earlier in this report) rather than protecting privacy of end consumers. As a consequence, it needs to be questioned whether similar principles - as originally suggested by Pachube- could apply in a similar way to Industry 4.0.

While Intellectual Property, industrial espionage and cyber criminality might be the primary concern of data protection, one should not forget that personal data protection does still play a role for IND4.0. First, increasingly consumers can influence the production chain when personalising their products. Second, remote maintenance of products implies the

[228] https://hbr.org/2015/02/managing-privacy-in-the-internet-of-things

processing of personal data of the product owner. Third and probably most relevant, human-machine interaction in the IND4.0 context creates new challenges in respect to privacy of employees. An example about privacy concerns in the Industry 4.0 employment sector is illustrated in the box below.

Example on IND 4.0 and Privacy: Smart Glove

The product: A company in Munich developed a smart glove, called ProGlove. It is a wearable tool targeted at professional production processes. ProGlove enables its wearer to work faster and therefore more efficient, is easy to use and unlocks a new level of information and business intelligence for production management. More specifically, the glove uses sensing technology to pick up or transmit information from whatever a worker is handling, be it by scanning be it a barcode or wirelessly sending messages to a data center. ProGlove co-founder Paul Günter mentioned in an interview: "if you could create a way to use track and sense what people's hands were doing at work, you could gain vital information to help train workers and monitor productivity."[229]

Implications: While the advantages need to be clearly taken into account, the smart glove could also be used to monitor the movements of workers unrelated to the production process. For instance, it would allow gaining a precise picture of the wearer's work habits, performance and location. This data could be used or manipulated and thus should be regulated more closely.

Towards a solution

As shown in the example above, monitoring workers in a smart factory can contribute to a better understanding of the interaction of machines and humans; it can contribute to the detection of patters and ultimately lead to increased productivity. Nevertheless, monitoring workers is ethically sensitive and needs to be done sensitively and contain sufficient safeguards. Problems related to regulating privacy in the smart factory context are linked to intrinsic features of the smart environment itself: in practice data protection principles are not implementable due to technological procedures. For instance, access to data, data availability, data separation, onward transfer cannot be properly controlled and thus loose its value.[230]

When thinking of the "Internet-of-Things Bill of Rights" it seems to be the step in the right direction also in the IND4.0 context, as it puts the data subject back into control of his/her data. The principle of controlling own personal data can be considered deriving from the principle of informational self-determination.[231] In terms of how to implement these principles, self-regulation (e.g. company's voluntary commitment to general data protection principles in terms of access) might be the most cost-efficient and effective way (given its flexible nature). In more practical terms, it could be put forward as the fourth pillar of corporate social responsibility (next to sustainability, economic growth and community involvement).

Nevertheless, this is not sufficient since such a self-regulatory mechanism is lacking accountability and transparency, which is often essential for compliance. Therefore, certificates and regulatory oversight on issues related to data protection should be

[229] http://iq.intel.com/smart-gloves-let-fingers-talking/ and http://www.proglove.de/
[230] http://www.it-daily.net/it-sicherheit/datenschutz/10855-datenschutz-im-smarten-business-industrie-4-0-darf-nicht-zum-monitoring-4-0-werden
[231] Volkszählungsurteil, BVerfG, Urteil v. 15. Dezember 1983

included. Furthermore, a strong role of national data protection supervisory bodies is conceivable especially after the *Schrems v. Facebook* case.[232]

Case Study 2: Corporate / Business Identity Theft

Recently, the U.S. Department of Justice has reported that identity theft has become the number 1 for-profit crime in the United States.[233] While identity theft is not something new and is a commonly known threat, business or corporative identity theft is a less well-known problem and it is also difficult to define. Below two key issues need to be clarified:

- "Business identity theft is not an information security breach, or an incident involving the loss or theft of confidential consumer information that a business may possess. Rather, like its consumer crime counterpart, business identity theft involves *the actual impersonation of the business itself*. It can occur through the theft or misuse of key business identifiers and credentials, manipulation or falsification of business filings and records, and other related criminal activities intended to derive illicit gain to the detriment of the victimized business; and, to defraud creditors and suppliers, financial institutions, the business' owners and officers, unsuspecting consumers, and even the government.
- The term *corporate identity theft* is misleading, as corporations are not the only business entities that are victimized by this crime. Any type of business or organization of any size or legal structure, including sole-proprietorships, partnerships, LLCs, trusts, non-profits, municipalities and county governments, school districts, and corporations - are *all* targets of business identity theft."[234]

Example of classical business identity theft

A former bookkeeper of a small business in the US, whose responsibilities included: paying company credit card bills; issuing company credit cards to new employees; keeping track of expense records; and handling company mail, made use of her access for personal gain. More specifically, the former employee allegedly opened a credit card in the business owner's name and added a new card, opened a second company card in her own name, and fraudulently used yet another company card. All of the cards were allegedly used to make fraudulent personal purchases amounting to more than $100,000.[235]

It is not difficult to imagine what differs in respect to business identity theft in the IND4.0 context. With the Internet of Things the risks of business identity theft offenses will change: In the IND4.0 context the constellation of the involved persons, services, machines and sensors changes dynamically. This means that there are many different identities and multiple possibilities to attack a smart factory. Furthermore, machines do not have the option to take flexible decisions. This exacerbates the recognition, improvement and automatisation of security measures. The problem is less the machine-to-machine-identification but more that the attacker pretends to be a machine. It is thus necessary to establish a centralised monitoring system that processes different aspects of identity (such as: log-in data, patterns of communication or exchanged data amounts). In this way, a potential identity theft can be examined and –if suspicious- further investigated.[236]

As indicated, a solution to counter business identity theft is to strengthen monitoring mechanisms. Furthermore, data security measures need to be put in place. As illustrated in

---

232 C-362/14
233 http://www.businessidtheft.org/Education/WhyBusinessIDTheft/tabid/85/Default.aspx
234 ibid.
235 http://www.wlky.com/news/woman-accused-of-charging-more-than-100k-to-business-credit-cards/33398748
236 https://www.bmwi.de/BMWi/Redaktion/PDF/I/industrie-40-verbaendeplattform-bericht,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

Chapter 5.1 suitable security measures need to be implemented on multiple levels: (1) Security Through Design; (2) Limit Access and Limited Visibility; (3) Pattern Recognition; (4) Encryption; and (5) Establish a Security Culture and Security Knowledge. The interaction of all these different dimensions can mitigate risks of business identity theft. Nevertheless, it cannot fully prevent it, therefore companies should also have adequate cyber insurance in place. Interestingly another more institutionalised way of securing data and safeguard smart factories from risks such as identity theft, has been to join forces with cybersecurity companies through mergers or partnerships.[237]

Case study 3: ESPRC Research programmes

Two projects funded by the Engineering and Physical Sciences Research Council[238] – the UK's main agency for funding research in engineering and the physical sciences – taking place at the University of Nottingham have produced three industrial demonstrators of Industry 4.0 applications. Working together with partners such as Airbus, BAE Systems, IBM, Siemens, HP, PA Consulting, these programmes address some of the key challenges associated with Informatics in manufacturing and demonstrate how they can be implemented by industry.

1. **Evolvable Assembly Systems**[239]

Bringing together a multidisciplinary and multi sector partnership, this programme aims to define and validate the vision and support architecture, theoretical models, methods and algorithms for a new platform of open, adaptable, context-aware and cost-effective production.

In a context of global value chains, production in high labour cost areas such as the UK is often restricted to processes such as the assembly of final products based on parts and components supplied from emerging economies. This is particularly the case in sectors such as automotive, aerospace, pharmaceutical and medical industries. Manufacturers based in high labour cost countries can enhance their competitiveness by transforming their currently capital-intensive assembly lines into smart systems that can react to external and internal changes in product requirements. This requires a radically new approach away from the current reconfigurable manufacturing and toward development of future assembly systems that can continuously evolve.

The research programme breaks with traditional approaches and is guided by the following foundational research pillars: Product-Process System Evolution; Data Analytics; Knowledge Modelling; Emergence Engineering; and, Open Manufacturing

Activities within the programme include defining concepts, creating models and methods for self-learning, prototyping selected instances of the reference architecture, as well as generating scenarios and prototyping demonstrators for evaluation and validation of the proposed models. The model of the programme is illustrated in the figure 1.

The findings from the research will benefit both private sector stakeholders such as large firms, SMEs and supply chain organisations as well as the wider public. From a policy perspective the research will provide a national focal point for future research in this exciting topic, through a series of road mapping activities supported by the University of Nottingham.

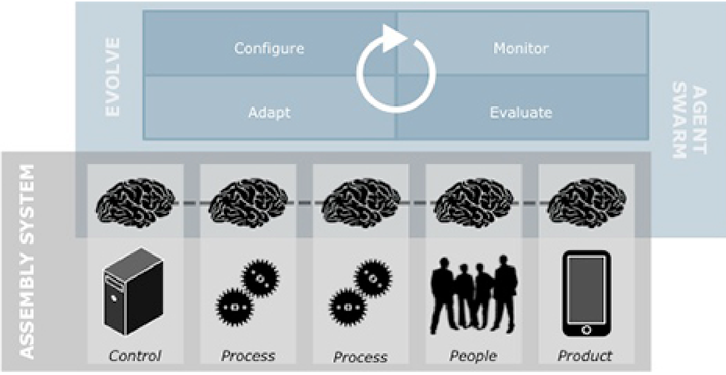
---

[237] Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries, 2014, Boston Consulting Group. Written by: Michael Rüßmann, Markus Lorenz, Philipp Gerbert, Manuela Waldner, Jan Justus, Pascal Engel, and Michael Harnisch

[238] www.epsrc.ac.uk/

[239] www.nottingham.ac.uk/ifam/research/collaborative/evolvable.aspx

Figure A.1 – Evolvable Assembly Systems illustration



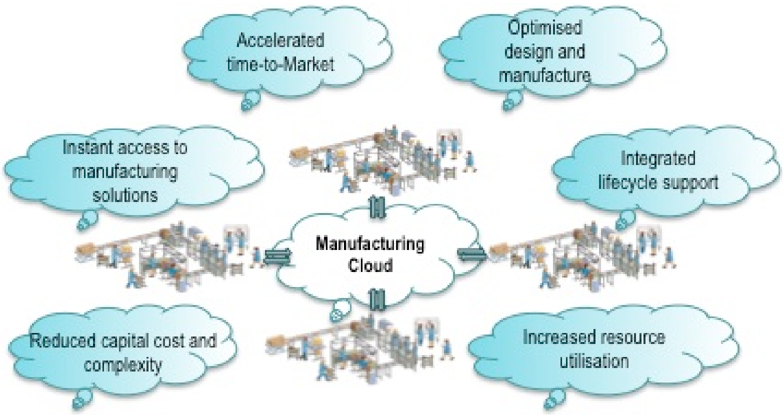
2. **Cloud manufacturing**[240]

This programme investigates how digital technologies such as cloud computing and crowdsourcing[241] can enable 'on demand' cloud manufacturing. By replacing conventional high capital expenditures with pay-as-you-go manufacturing services and through-life support, new product information, volume manufacturing and lifecycle management could be radically transformed. This may also enable new market entrants to arise by making away with the need for large capital investments.

Activities within the programme include defining concepts, creating models and methods for the manufacturing cloud as a complex networked service system, building manufacturing-specific data mining, process and optimisation methods, prototyping selected instances of the reference architecture, as well as generating scenarios and prototype demonstrators for evaluation and validation of the proposed models.

The outcomes of the programme should benefit the research community by establishing a long-term research agenda in cloud manufacturing at the interface between computer science, human factors and operations management. Moreover, it should benefit the private sector through direct cooperation with supply chain networks. The model of the programme is illustrated in the figure below:

Figure A.2 – Cloud manufacturing illustration



240 http://www.nottingham.ac.uk/ifam/research/collaborative/cloud.aspx
241 Crowdsourcing refers to the sourcing of tasks or activities to a wider circle of decentralised actors.

Case study 4: Developments in the USA and "Advanced Manufacturing"

Questions surrounding competitiveness and the role of advanced manufacturing and the Internet of Things are also high on the policy agenda in the USA. The aim of this case study IS to focus on the USA, INCLUDING the findings of the recent Brookings Report to identify developments in that country and see if there are implications for the EU.

In the USA there is a significant movement in industry towards integration of manufacturing industry with the latest developments in IT, mechanical engineering and the internet. The main institutional initiatives identified are the Manufacturers Alliance for Productivity and Innovation (MAPI)[242], the Smart Manufacturing Leadership Coalition (SMLC) and the Industrial Internet Consortium (IIC). The National Network for Manufacturing Innovation (NNMI) will also be mentioned.

Advanced Manufacturing

A recent report by the Brookings Institution reviewed America's Advanced Industries in some detail.[243] Although a wider concept than Industry 4.0, the notion of advanced industries has much in common with the advanced manufacturing sector in Europe, although it does include services (e.g. software) and energy as well as manufacturing. Some key findings from the perspective of this report are:

- Although the total number of the jobs in the sector has stayed constant 1980 to 2010, output per job has grown at an annual rate of 5.4%, much faster than other sectors. Since 2010 output and employment growth in the sector (especially services) has led the US economy.
- The sector provides high quality and well rewarded jobs compared to other secotrs.
- The USA is losing ground to other countries in advanced industry competitiveness.
- The sector faces a labour supply challenge, STEM occupations, and standards compare poorly with other developed countries
- Advanced industries tend to cluster in large metropolitan areas
- There are sharp regional variations in the availability of skills, with concentrations in a few metropolitan areas which place a drag on many other metropolitan areas in terms of their ability to support advanced industries.

The report's authors conclude that: "the last decade raises especially sobering questions, not just about trade policy, but over the long-term viability of the sector … too few regional advanced industry ecosystems now retain the technology inputs, labor pools, and supplier density to generate the synergies that drive global competitiveness."[244]

The SMLC[245]

According to the SMLCs publicity material, it is "a non-profit organization comprised of manufacturing practitioners, suppliers, and technology companies; manufacturing consortia; universities; government agencies and laboratories. The goal is to build a cloud-based, open-architecture platform that integrates existing and future plant level data, simulations and systems across manufacturing seams and orchestrate business real time action.

---

[242] https://www.mapi.net/
[243] footnote
[244] Ibid., p.8
[245] https://smartmanufacturingcoalition.org/

Smart Manufacturing (SM) is described as integrating network-based data and information that comprises the real time understanding, reasoning, planning and management of all aspects of a manufacturing and supply chain enterprise. SM is facilitated through use of advanced sensor-based data analytics, modelling and simulation in real-time. SM is manufacturing in which all information is available when it is needed, where it is needed and in the form it is most useful—infusing manufacturing intelligence throughout the lifecycle of design, engineering, planning and production. Unfortunately, a cost effective infrastructure to integrate real-time manufacturing intelligence and active management across the control systems of an entire production operation does not exist today.

Industry 4.0 and the Industrial Internet Consortium (IIC)

The research division of MAPI has produced a document that sets out some of the similarities and differences between Industry 4.0 and the IIC.[246] These are listed in the table below:

IND 4.- and Industrial Internet consortium - Comparison	
Industry 4.0	**Industrial Internet Consortium**
Authors/ Drivers of the programme	
German Federal Government: High-Tech Strategy 2006 -> High-Tech Strategy 2020 (2010), ->High-Tech Action Plan 2020 (2012) -> Platform Industrie 4.0. Federal Government has invested >€ 400m. Timescale: First models end of 2016; all - encompassing processes for reproduction 2030.	*Large multinationals*: GE, AT&T, Cisco, INTEL and IBM (2014). Non-profit organisation acting as a resource for ideas and test-beds, catalysing industry, academia and government
Key stakeholders	
Federal government ministries: Education and Research, Economics and Technology *Academia*: Fraunhofer-Gesellschaft, National Academy for Science and Engineering, German Research Center for Artificial Intelligence and others *Private sector*: Platform Industrie 4.0 – BITCOM, VDMA, ZVEI, Bosch, SAP, etc	*Business driven*, approx. 12 staffers based in the USA and Europe. Membership is open, fees are rated by firm size, approximately 170 members including Bosch, SIEMENS, SAP, Fraunhofer, academic institutions from > 2 dozen countries including China, India, etc.
Support platforms	
"The ultimate goal of Industrie 4.0 is to safeguard a sustainable competitive advantage of Germany's manufacturing base … we must train German industry to build and install CPS, and …make these remain competitive worldwide"[247] "Germany sits at the top of world trade with its research intensive products"[248]. The federal government is responsible	To enable and accelerate the adoption of the internet om any type of business process, manufacturing or otherwise. Companies join to benefit from sharing best practices. The focus is on the interoperability of products and technologies and "test beds"
Sectoral focus	
Manufacturing (22% GDP) - concern about falling behind in the marriage of hardware German strength) and software/ digital technologies conceived outside Germany	Manufacturing focus but wider scope (65-70% GDP – including agriculture and infrastructure).

[246] Bledowski, K. MAPI The Internet of Things: Industrie 4.0 vs the Industrial Internet (23/07/2015)
[247] Ibid
[248] Ibid

IND 4.- and Industrial Internet consortium - Comparison	
Industry 4.0	**Industrial Internet Consortium**
Technological focus	
Embedded systems, automation, robotics – CPS that can connect to a supply chain	Anything that can be connected to the internet, big data, with data feedback and raising efficiency.
Geographical focus	
Focused on Germany, and using German taxpayers' money to that end. Given the importance of Germany's manufacturing sector it does have wider EU impacts.	World-wide focus, which could lead to a more rapid closing of the productivity gap between advanced and emerging nations.
Corporate focus	
Focusing on carrying the message to and educating Germany's SMEs.	Dominated by large companies (e.g. ABB, Siemens, China Telecom, Mitsubishi) - open to all, has SME members.
Optimisation focus	
CPS focuses on manufacturing efficiency	Return on any assets
Standardisation focus	
Developing standards is central but as yet it is not clear how this should proceed.	To provide guidance to standards organisations
Economic approach	
Tends to be a theoretical description of future manufacturing - generic change process over the next 10-20 years.	Strong orientation to the present and working with what is currently available

The National Network for Manufacturing Innovation (NNMI)[249]

The NNMI provides a manufacturing research infrastructure where U.S. industry and academia collaborate to solve industry-relevant problems. The NNMI is a network of Institutes for Manufacturing Innovation that each has a unique focus, but a common goal to create, showcase, and deploy new capabilities and new manufacturing processes. They provide a stage where industry, academia, and government partners can share resources, collaborate and co-invest to nurture manufacturing innovation and accelerate commercialization.

The Digital Manufacturing and Design Innovation Institute (DMDII), launched in 2014 focuses on Integrated Digital Design and Manufacturing. DMDII is the flagship research institute for applying cutting-edge digital technologies to reduce the time and cost of manufacturing, strengthen the capabilities of the U.S. supply chain and reduce acquisition costs for the U.S. Department of Defense. It develops and demonstrates digital manufacturing technologies, deploys and commercializes these technologies across key manufacturing industries. The goal is to create product and manufacturing process definitions simultaneously. Founding organization: UI Labs; the Federal Partner is Department of Defence. Federal funding - 70 million, match funding $106 million, >73 partners.

Case study 5 Developments in China

As a comparator to both Industry 4.0 and the IIC, developments in China are outlined in this case study. The two main initiatives in China are Internet Plus (IP) and "Made in China".[250]

Internet Plus (IP)

[249] Web: http://dmdii.uilabs.org
[250] Bledovski

IP is a plan issued by the State Council aimed at linking retail, manufacturing and the cloud. It is aimed at upgrading traditional industries, searching for new technologies, and spreading internet applications into the public sector. An Action Plan called Internet Plus Circulation targeting the distribution sector was released in May 2015 by the Ministry of Commerce, focusing on developing e-commerce in SMEs. The plan is linked to the 13th Five-Year Plan, and details many targets to be achieved by 2016 (e.g. to establish 60 e-commerce demonstration bases). The plan has an important urban-rural focus and aims to lessen the urban-rural divide.

A July 2015 action plan identifies four primary goals:[251] to upgrade and strengthen the security of Internet infrastructure; to expand access to the Internet and related technologies; to make social services more convenient and effective; and, most importantly, to increase both "quality and effectiveness" of economic development—in other words, move away from labour-intensive manufacturing to a higher point on the value chain. By 2025, the plan says, Internet Plus should be an "important driving force of innovative economic and social development."

The action plan maps development targets and supportive measures for key sectors, which the government hopes can establish new industrial modes, including mass entrepreneurship and innovation, manufacturing, agriculture, energy, finance, public services, logistics, e-commerce, traffic, biology and artificial intelligence. It outlines eleven areas for government work to achieve these goals by 2025, all of which are linked to other key initiatives including: entrepreneurship and innovation, collaborative manufacturing, modern agriculture, etc.

In addition, *Guiding Opinions* included 25 relevant supportive measures, categorized into five parts: Policy Environment; New-Generation Information Infrastructure Development; Public Resources Sharing; Business Operation Support; and, Safety Regulations.

By 2025, IP is to become a new economic model and an important driving force for economic and social innovation and development.

Made in China 2025

This plan was conceived by the Ministry of Industry and Information Technology working with the China Academy of Engineering. It is strictly focused on manufacturing and moving industrial companies up the value chain and to develop a domestic innovation capacity with a "Made in China 2025" roadmap and has been seen as China's equivalent to Industry 4.0: an effort to create a manufacturing revolution underpinned by smart technologies.

The initiative (the first of three 10 year stages) has three dimensions:

- A sectoral dimension (10 priority areas)
- Improvements in very low tech, low-tech, mid-tech and high-tech. There is a lot of variation in Chin and the aim is to move it all upwards.
- Improved competiveness of Chinese products across price points: low – vs Vietnam; middle vs ASEAN and high – developed world.

The ambition is to turn China into a "strong" manufacturing nation within a decade, with the priority on digitalisation and modernisation of 10 sectors. [252]If successful, it would be a huge step up for China from the "world's factory", which for decades saw it churn out

[251] Davison, L. E. (July 17, 2015); 'Internet Plus' and the Salvation of China's Rural Economy A new "Internet Plus" plan may expand opportunities for China's rural residents.

[252] http://www.scmp.com/news/china/economy/article/1814281/made-china-smart-revolution-blueprint

mainly cheap, low-quality clothes, toys and other goods. The ten-year plan calls for "promoting breakthroughs in 10 key sectors."

The plan calls for financial support for these industries as well as "institutional reforms" – what that means, exactly, will be determined later, when new policies designed to advance the plan are rolled out in the coming years. The plan, briefly announced during the national political meetings in March and fleshed out in more detail on May 18, has excited the market, pushing manufacturing stocks to new highs. According to Citigroup, China plans to invest 8.02 trillion yuan in the next few years to modernise and transform its industry - a far more ambitious programme than Europe's plan to spend an estimated €1.35 trillion (HK$11.50 trillion) on similar improvements over a much longer timeframe of 15 years.

The plan proposes four measurements to access the companies' maturity in Industry 4.0 terms, including the creativity, quality benefit, integration of industrialization, and information and green development. For example, the plan stipulates that the percentage of research and development (R&D) funds of large manufacturing companies should increase from 0.95% in 2015 to 1.68% by 2025, and the value-adding ratio of the manufacturing sector should increase by 4%. Use of computer numerical controls (CNC) should increase by 30%, and the energy consumption of manufacturers should decrease by 34%.

The Ministry of Industry and Information Technology (MIIT) released the 2015 smart manufacturing projects, including 94 projects covering scientific research institutions and enterprises incorporated into the list, symbolizing the start of the smart manufacturing project in the Made in China 2025 plan. Li Dong, co-director of MIIT's equipment department, said the smart manufacturing projects will be further expanded by 2016 and fully put into operation in 2017.[253]

Made in China 2025 will focus on five major projects and to realise them China will mostly rely on SOEs, as the plan will be market-oriented but guided by government officials and mostly government agencies. Among the projects there are new innovation centres (through abundant government's fiscal and financial support – possibly modelled on the US), green demonstration and smart manufacturing, self-sufficiency in infrastructure, indigenous R&D – China is becoming the biggest spot for multinational companies to move R&D departments – and intellectual property (IP) projects for high-value equipment.

Chinese IND 4.0 patents

Results of a recent study by Fraunhofer IAO of patents registered in China over the last three years for Industry 4.0 technologies have been published.[254] This shows that Chinese researchers have patented important inventions in the fields of wireless sensor networks, embedded systems, low-cost robots and big data, indicating that China will be leading the pack when it comes to production data in the future. In terms of the number of patents filed for Industry 4.0 technologies, China has far outstripped the United States and Germany.

Companies that want to market Industry 4.0 solutions in China need to know the areas in which the Chinese have already registered key innovations. These cover the entire span from energy-efficient technologies intended for reliable industrial networks to robotics, where China's largest robot manufacturer, SIASUN, has registered some 140 inventions a year for the past three years – and there are 300 or so other Chinese robot manufacturers also active in the market.

---

[253] Jin, A. editor-in-chief, *Control Engineering China*. Edited by Joy Chang, digital project manager, *Control Engineering*, jchang@cfemedia.com.

[254] Study on monitoring Chinese industry 4.0 technology and patents, Jun 24, 2015

But, Fraunhofer asks, what does patent quantity say about the quality of all these inventions? They suggest that the relatively low innovative quality of Chinese utility model applications and patent submissions is striking in the application of Industry 4.0 technologies. They are usually formulated in very imprecise terms

Made in China 2025 and Industry 4.0

In July 2015 Germany and China agreed to intensify cooperation on digitization of industrial processes, or Industry 4.0.[255] Germany's economy and energy minister was in Beijing to advance German-Chinese economic cooperation on the development of Industry 4.0 technologies in a meeting with China's minister for industry and information technologies. They signed an agreement promoting cooperation of German and Chinese firms in "intelligent manufacturing and digital networking of production processes," according to a statement from Germany's economics and energy ministry. That will involve developing links between the German government's "Industry 4.0" strategic industrial development program and China's "Made in China 2025 " initiative.

The ministerial agreement sets out "general bases of cooperation" which include effective protection of intellectual property rights, voluntary decision of companies on whether or not to transfer technologies, joint German-Chinese development of norms and standards, data security for the firms involved and efforts to improve the framework conditions for entrepreneurs.

However, it was pointed out that China has a strategy of fostering national champions in specific industries - and those companies are already playing in the premier league globally. As such, it was commented that "It's extremely difficult and very expensive for foreign industrial firms setting up in China to achieve data security ... Midsize companies can't afford it. It's not clear it's possible even for very large and deep-pocketed firms to prevent data or IP theft."

China and the global market for robots

Statistics from the International Federation of Robotics showed that China’s demand for industrial robots has been growing at a speed of 25 per cent a year. It was estimated that the market value in China could soon reach 100 billion yuan, which has led to a boom in Chinese robot manufacturers. However, the domestic market is dominated by international brands such as ABB, Fanuc, Yaskawa and Kaku.

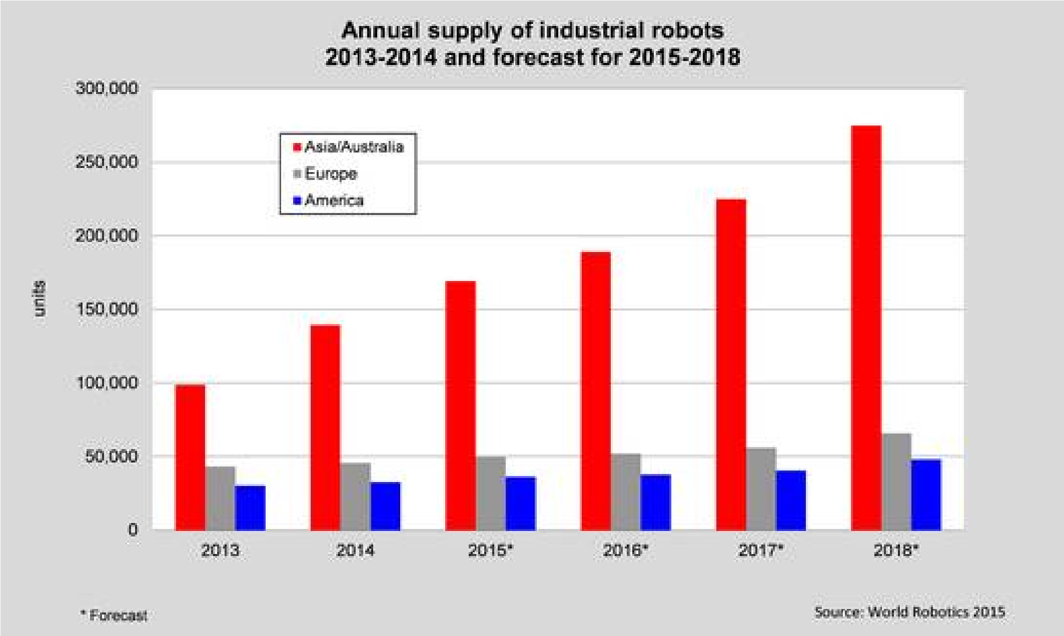
By 2018, global sales of industrial robots will on average grow by 15 percent year on year, and the number of units sold will double to around 400,000 units. [256] "The main driver of this is the global competition of industrial production. The automation witnessed by the automotive sector and the electrical/electronics industry comes out top here with a market share of 64 percent," says IFR President Arturo Baroncelli. *A new generation of robots is a strong echo of various demands — the 'Made in China 2025' plan, US re-industrialization, Japan's rejuvenation strategy and the EU's Industrial 4.0 all symbolize the new age of equipment's transformation and a changing production mode*," said Dr. Daokui Qu, CEO of SIASUN Robot & Automation.

Worldwide annual sales of industrial robots rose by 29 percent in 2014. Five major markets represent 70 percent of total global robot sales volume: China, Japan, USA, South Korea and Germany. China's rapid automation, says the IFR, represents a unique development in robotics history.

---

[255] Reference2015-09-10 | 14:00 - 17:10

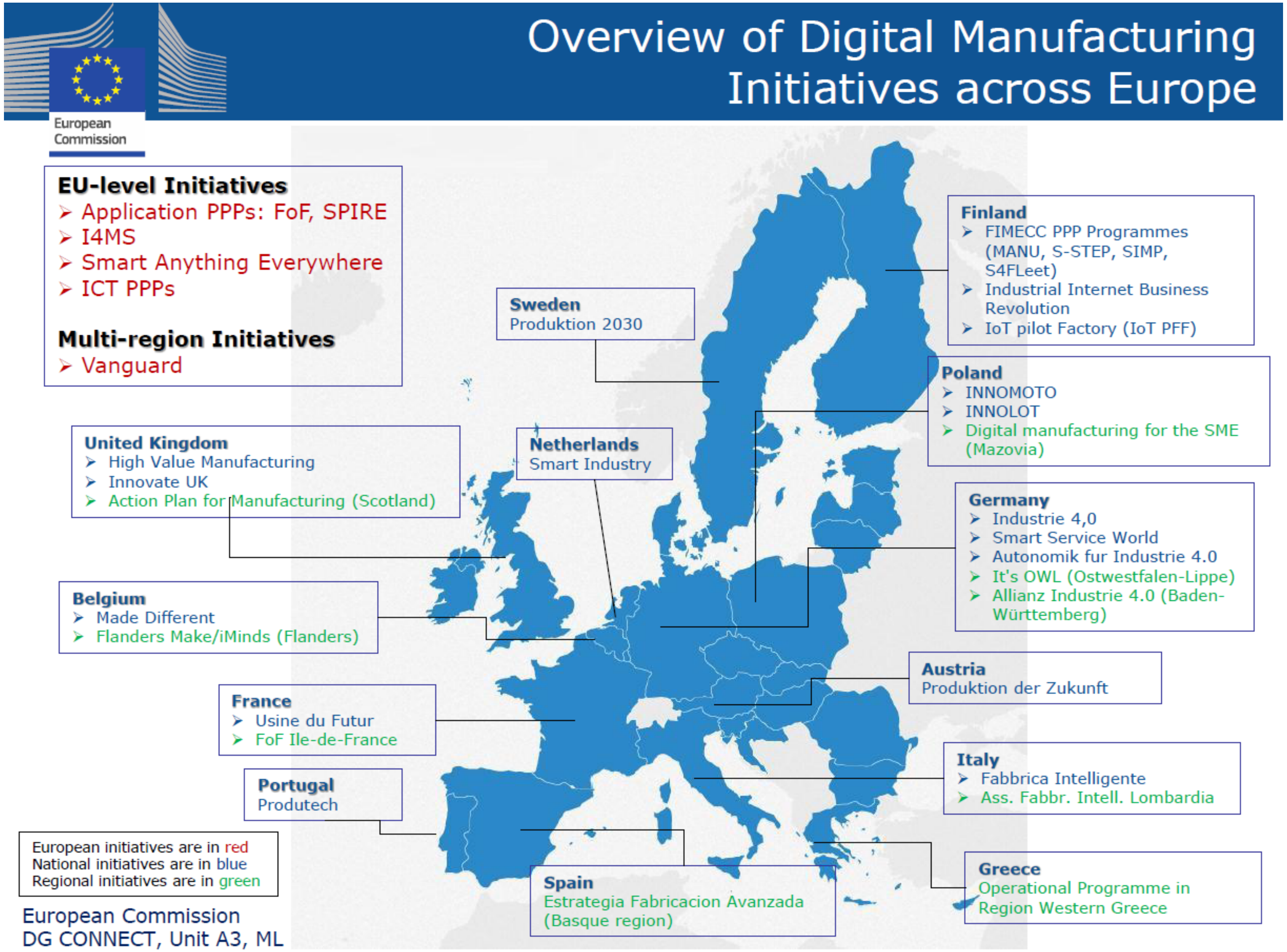
[256] Burns, A. “Uncaged. New statistics from the International Federation of Robotics Illustrate converging patterns of data, efficiency and demand” Site Selection http://siteselection.com/onlineInsider/uncaged.cfm



"The number of industrial robots sold increased by 56 percent alone last year in comparison to 2013," says the report, calling China both the largest and fastest growing robotics market in the world. "The potential remains enormous despite the recent economic downturn. Chinese production industries currently have a robotic density of just 36 units per 10,000 employees. By comparison, front-runner South Korea deploys 478 industrial robots per 10,000 employees, followed by Japan (315 units) and Germany (292 units). It is estimated that more than one-in-three of the global supply of industrial robots will be installed in the Republic of China in 2018. Production industries in the United States deploy just 164 industrial robots per 10,000 employees right now, says the IFR, but reshoring may be having an effect. In 2014 the number of installed robots increased by 11 percent to around 26,000 units — making it third in the world. In Germany, the sales figures increased by around 10 percent in 2014 to about 20,100 units — to date the largest number of sales registered within twelve months.

For the second year in a row, China was the world's biggest industrial robots market. In 2014, sales volume reached about 57,000 units, which amounted to a one-fourth of the total global sales. Between 2009 to 2014 sales of industrial robots increased by an annual average of 59 percent. It is estimated that more than one-in-three of the global supply of industrial robots will be installed in the Republic of China in 2018. Foreign robots occupy the main market. In China, foreign robot suppliers increased their sales by 47 percent to about 40,000 units, accounting for a share of 71 percent of the whole Chinese market. Domestic robot suppliers increased their sales by 76.6 percent to about 16.000 units, only accounting for a share of 29 percent.

APPENDIX B: OVERVIEW OF DIGITAL MANUFACTURING INITIATIVES



EU – level initiatives

1. Application PPPs : FoF ; SPIRE ;

The Sustainable Process Industry through Resource and Energy Efficiency (SPIRE) Public-Private Partnership (PPP)[257] was launched in 2012 as part of the Horizon2020 framework programme representing more than 130 industrial and research process industry stakeholders from over a dozen countries EU Member States. Via European Technology Platforms and Industry Associations, it covers the chemical, engineering, and ceramics industries, amongst others. The partnership aims to develop enabling technologies and best practice solutions for existing large-scale production value chains in order to improve resource and energy efficiency. The focus is on funding research and the associated targets are summarised in a roadmap leading up to 2020 and 2030.

2. I4MS

ICT Innovation for Manufacturing SMEs (I4MS)[258] is an EC-led initiative to support innovative European manufacturers, including SMEs, with adopting information and communication technologies to address their needs to access to technology, infrastructures and new markets. The initiative has a budget of € 77 mn and was launched in 2013.

The initiative is linked to FP7 research and covers four major areas of leading technologies: Robotics; HPC cloud based simulation services; Laser based applications; and, Intelligent sensor-based equipment. The initiative operates through two main instruments: Seven ICT projects in the above-mentioned areas selected through open calls; and, sharing of best practices and lessons learnt, including presentation of experiment results, etc.

3. Smart Anything Everywhere

Smart Anything Everywhere describes a set of innovation initiatives launched in FP7 and expanded under H2020 supporting SMEs in digital value creation. The budget is € 25 Mn supporting 23 European competence centres in the components and systems value chain across 11 Member States will start from January 2015 to support 100 user-supplier experiments with 200 SMEs and mid-caps. Currently, Smart Anything Everywhere constitutes projects selected under ICT1 and ICT2 of Work Programme 2014/15.

4. ICT PPPs

Multi-region initiatives

5. Vanguard

The 'Vanguard initiative for New Growth through Smart Specialisation'[259] aims to help European regions develop by fostering entrepreneurial innovation and industrial renewal. It seeks to facilitate the creation of partnerships to support innovative SMEs and regional innovation ecosystems. Tools employed are pilots and large scale demonstrators. The initiative seeks to undertake investments to help Europe lead in new industries and develop lead-markets. Priority areas include those identified in the Industrial Policy Communication of October 2012[260]. The role played is mainly that of a coordinator, ensuring that investment strategies/ priorities are aligned at regional level to support the emergence of specialisation clusters as well as to internationalising these cluster initiatives in cross-border and interregional European partnerships.

[257] http://www.spire2030.eu/
[258] http://i4ms.eu/
[259] http://www.s3vanguardinitiative.eu/
[260] COM(2012) 582 final. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0582:FIN:EN:PDF

CAT: QA-02-16-198-EN-C (paper)
CAT: QA-02-16-198-EN-N (pdf)

DIRECTORATE-GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT A
ECONOMIC AND SCIENTIFIC POLICY

Role

Policy departments are research units that provide specialised advice to committees, inter-parliamentary delegations and other parliamentary bodies.

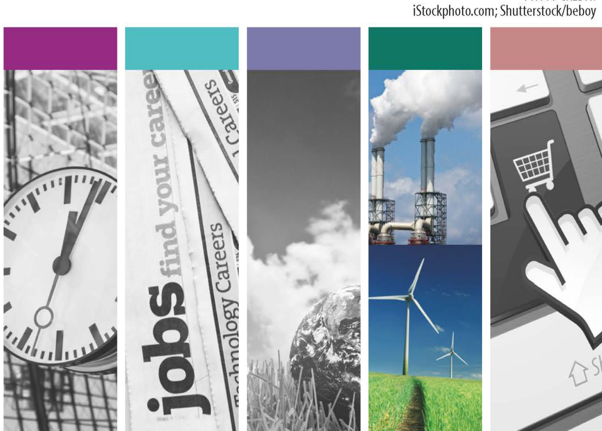
Policy Areas

- Economic and Monetary Affairs
- Employment and Social Affairs
- Environment, Public Health and Food Safety
- Industry, Research and Energy
- Internal Market and Consumer Protection

Documents

Visit the European Parliament website:
http://www.europarl.europa.eu/supporting-analyses

PHOTO CREDIT:
iStockphoto.com; Shutterstock/beboy



ISBN 978-92-823-8816-7 (paper)
ISBN 978-92-823-8815-0 (pdf)

doi: 10.2861/665669 (paper)
doi: 10.2861/947880 (pdf)

Publications Office

Industry 4.0