



Summary Report 2nd GLORIA Workshop on:

Global corporate value chains and innovation networks in the fourth industrial era: new models of production and work organisation

Brussels, 17 May 2019

Alexander Tübke, Mafini Dosso, Zóltan Csefalvy, Nicola Grassano, Lesley Potters and Sara Amoroso^{1 2}

1. INTRODUCTION

This second GLORIA workshop is part of the **Global Research & Innovation Analyses³** (GLORIA) project undertaken jointly between the Commission's Joint Research Centre and the Directorate General for Research and Innovation. The most visible outcome of the GLORIA project are the **EU Industrial R&D Investment Scoreboards** providing economic and financial data and analysis of the top corporate R&D investors from the EU and from abroad, based on company data extracted directly from the financial accounts of each company. The Scoreboard is published annually since 2004 in order to provide a reliable, up-to-date **benchmarking tool** for comparisons between companies, sectors, and geographical areas, as well as to **monitor and analyse** emerging investment trends and patterns. It also aims to **raise public awareness and support for R&D investment** among individual companies and policy makers, and **encourages companies to disclose** information about their R&D investments. Additional research surrounding the R&D and innovation dynamics, main trends and their wider impact is performed by the JRC and in collaboration with other Commission services, external experts and the scientific community.

The **GLORIA workshops** are held periodically about twice a year in order to **update on issues addressed** within the project and our research and to obtain **feedback from the science-policy-industry nexus** about how the GLORIA activities are best serving their current and future needs. Up to now, ten previous workshops have been held.⁴

¹ European Commission, Joint Research Centre (JRC), Directorate B Growth and Innovation, B3 Unit: Territorial Development, Edificio Expo, C/ Inca Garcilaso 3. 41092 Seville, Spain

² The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission

³ See: <http://iri.jrc.ec.europa.eu/home/>. The activity is undertaken jointly by the Directorate General for Research and Innovation (DG RTD.A; see: <http://ec.europa.eu/research/index.cfm?lg=en>) and the Joint Research Centre, Directorate B Growth & Innovation (JRC-B; see: <https://ec.europa.eu/jrc/en/science-area/innovation-and-growth>).

⁴ See: <http://iri.jrc.ec.europa.eu/workshops.html>

2. THEMATIC BACKGROUND AND RATIONALE

The emergence and development of new, advanced technologies and materials have spurred **tremendous changes in corporate strategic approaches and the organisational models underlying the production, innovation and work systems** (Smit *et al* 2016; Ulmann, *et al* 2017; Porter & Heppelman 2014). Although still many years away, the full integration of these new technologies and materials and the multiplication of their applications - *Internet of Things, big data and cloud computing, robotics, artificial-intelligence based systems and additive manufacturing, smart factory, precision farming, fintech, microengineering, predictive medicine, synthetic biology, etc.* - are already bringing many opportunities and challenges for organisations and people through further digitalization, automation, connectivity and data intelligence possibilities. At the EU policy level, Key Enabling Technologies (KETs) and advanced manufacturing have for long been considered as important drivers for the modernization and the development of new industries, also in tackling broader societal challenges in areas related for instance to energy, environment and resource scarcity.⁵

Referred to as the **fourth industrial revolution (I4.0)**, these new changes have come with increasingly geographically distributed production and innovation resources, reflecting novel dynamics into global value chains (GVCs) and innovation networks (GINs) (e.g. Gereffi 2018; Cano-Kollmann *et al* 2018; Ramirez 2018; OECD 2016; Liu *et al* 2013). New products and innovations are increasingly resulting from fragmented GVCs and dispersed GINs. The integration of I4.0-enabling technologies provides multiple possibilities for firms, such as the optimization of production and supply chain management, the reorganization of suppliers relations, the reduction of failures and the increase in manufacturing efficiency, the improvement of traceability, transparency and customer-centric and customizable products or the introduction of new work management systems, just to name a few. Given the increasing intensity of competition, the reduction of products' and technologies' life cycles and the potentially huge gains expected from first mover advantages, firms are incentivized or pushed to redefine or innovate in their business models (see the box of definitions). **The transition to the fourth industrial era affects the way firms create value** (performance of tasks internally, relations with suppliers and other business partners), **how they capture value** (monetization of the offers) and **how they offer value** (for instance, servitization or more integrated or bundled products and services) (e.g. Müller *et al* 2018a).

⁵ See the Europe 2020 Strategy and the different EC communications in order to have an overview of the EC's framework for industrialisation, innovation and digitalization (see for instance, EC, 2009; EC, 2010a,2010b; EC, 2010c, EC, 2010d, 2012, 2014, 2015, 2016, 2017a, 2017b).

"A Stronger European Industry for Growth and Economic Recovery" (EC COM, 2012) lists six fast-growing initial priority areas including, *Markets for advanced manufacturing technologies for clean production; Markets for key enabling technologies (micro- and nano-electronics, advanced materials; industrial biotechnology; photonics; nanotechnology and advanced manufacturing systems); Bio-based product markets; Sustainable industrial policy, construction and raw materials; Clean vehicles and vessels; Smart grids* (EC, 2012).

Importantly, the emergence of new geographical configurations of production and innovation have come with a gradual shift from trade in goods to **trade in activities**⁶ performed through global and local networks of places, organisations and people (e.g. Gereffi 2018; Cano-Kollmann et al 2018; Ramirez 2018). At the same time, increasing value is generated from **more knowledge-intensive intangibles** arising from specialized knowledge-based activities, which are also subject to outsourcing and offshoring to research centres/universities, Contract Research Organisations (CROs) and to suppliers, from both developed and emerging economies (see the policy briefs by Dosso et al 2019, 2017).

The rapid changes in GVCs and GINs configurations enabled by the application of I4.0 technologies have also important implications for the new models of work organisation and workplaces management. So far, most of the debate has focused on phenomena of **polarization and skill-biased technological change**. In a nutshell, greater automation and digitalization are expected to displace jobs with highly predictable tasks, which are often low-skills, and to increase the demand for jobs with few predictable tasks (software and data experts, engineering, etc.), which are often high-skill. This leads to a simultaneous increase of employment in both the highest and lowest occupational levels and a decrease in middle-skilled occupations. Skill-biased technical change refers to shifts in technology of production that favour skilled labour over unskilled labour (see for instance Okazawa 2013 for a discussion of the effects of technological change on labour market and wage inequalities).

However, on the one hand, we need more industrial and firm-level insights in order to better characterize and anticipate⁷ the implications of the new paradigm on the new world of employment – **Workforce 4.0** –, for instance, in terms of conditions and capabilities, qualifications, skills needs, technical aptitudes or awareness. Indeed, pressures at both organizational and plant levels can entail complex unbalances between control, liability, flexibility, autonomy and empowerment, and concerns from the greater human-machine interactions allowed by the diffusion of advanced technologies (e.g. Craglia et al., 2018; Cirillo et al., 2018; UN DESA/DPAD, 2017). The patterns of these unbalances may differ much across industries and types of occupations (e.g. Brynjolfsson et al., 2018; Frey and Osborne, 2017). Besides, I4.0-enabling technologies and processes also bring up many legal and accountability concerns and would certainly require the setting up of completely new forms of working and social contracts, which should account better for the socio-political aspects of digitalization (e.g. Birkel et al., 2019; Burh and Stehnen, 2018). On the other hand, **I4.0 can also bring many benefits to employees** through enhanced human learning through intelligent assistance systems as well as human machine interfaces that lead to increased employee satisfaction in industrial workplaces (Müller et al 2018b).

⁶ Also referred to as fine-grained GVC activities (e.g. Gereffi and Sturgeon 2013) that should underline the development of GVC-oriented industrial policies.

⁷ See the notion of anticipatory regulation (NESTA 2017).

Relatedly, the benefits, opportunities and challenges of I4.0 are not only technical and economic. Indeed, a key societal and policy concern is to ensure that the transition towards I4.0 and the adoption of new production, innovation and work models **are sustainable⁸ from the – economic, social and environmental – perspectives** (European Commission 2019; UN 2015). EU, the Member States and regions are also expected to contribute to transform the industrial behaviours in order to “*Ensure Sustainable Consumption and Production patterns*” (Sustainable Development Goals 12 of the 2030 UN Agenda) and thereby contribute to the creation of sustainable economic value, social value and environmental value. However, so far, economic, ecological and social aspects, relating to the Triple Bottom Line of sustainability, are often investigated in isolation rather than regarding their interdependencies. However, balancing effects in all three dimensions against each other is vital in order to grasp the full benefits of Industry 4.0 and to accelerate its implementation (Birkel et al., 2019; Müller & Voigt, 2018).

3. SCIENCE-TO-POLICY QUESTIONS

The following broader policy questions were formulated and tackled by an introductory keynote speech and the subsequent short presentation and discussions:

- What are the main **Industry 4.0/Workforce 4.0 (I4.0)** issues and trends? (*Workforce 4.0 can refer, for instance, to the new (mix) of skills or aptitudes, of capabilities and the related emerging organisation of work within and across firms, that are driven or triggered by the adoption and diffusion of Industry 4.0 technologies and their applications*).
- What are the implications of I4.0 for the current and future **glocal – global + local – value chains** (GVCs) and for the development of **Innovation Networks at the local and global levels** (*organisation of production, innovation processes and organisation of work*)?
- Are there new **Ownership, Location and Internationalization advantages** in the I4.0 context? Can these serve as an **incentive for re-investing/re-shoring**?
- How can policy better account for the **heterogeneous needs and weaknesses of regions and firms** with respect to I4.0 (infrastructure, skills, information, awareness and readiness, etc.)?

The day was concluded by a **policy round table** where the 36 participants from the science-policy-industry nexus discussed the policy relevance of the evidence presented and ideas on how to bring forward the research agenda to support policy-making in addressing these new realities.

⁸ See also the Box of Definitions

4. EVIDENCE FROM THE GLORIA PROJECT AND KEYNOTE SPEECH

The JRC presented evidence relevant for the workshop theme collected within the GLORIA project, starting with a **conceptualisation** of Global Value Chains (GVCs) in Research and Innovation vs Global Innovation Networks (GINs) in- and outside the firm. Within firm R&D evidence has been collected in our R&D Scoreboards and Surveys, co-patenting within GINs and only more recently related to GVCs. Another project analysed case studies of 10 global R&D investors in pharmaceuticals, aerospace, automobiles and ICT to better understand the fragmentation of their R&D&I activities and the associated geographical distributions. There is not **only great heterogeneity between the interviewed companies in these three sectors, but also among the companies within the same sector**. Remarkable is a high focus for R&D and Innovation (R&D&I) activities for clinical trials in the pharma sector, which is prerequisite to get approval to bring new drugs on the market. Here, a high level of basic research outsourced to Contract Research Organisations (CROs). Also, the interviewed large automotive companies perform little basic research because this is **often performed by the smaller supplying companies in the GINs** that comprise the automotive sector. Also, the results from assessing the EU regional capabilities in developing digital technologies related to digital transformation (ICT patents) were presented. They show that the **leadership in ICT patents is mainly concentrated in the central EU**, together with Scandinavian regions and some regions in France and the UK. Eastern and Southern regions tend to show lower levels of patenting activity per capita. However, when looking at the patenting of innovative products that incorporate ICT patents, we see a much more dispersed map. It turns out that **a higher share of ICT patents is associated with lower shares of ICT-combined patents**. Regions specialised in ICT development rely more on international collaborations/spill overs.

The keynote speech by Salzburg University of Applied Sciences showed the current use of I4.0 at the industry level by various empirical surveys undertaken mainly in Germany and Austria, concluded by a comparative study between German and Chinese SMEs. As Industry 4.0 targets vertical and horizontal integration, i.e. within an organization and across supply chains, a key **barrier towards the implementation of I4.0 by SMEs is the issue of data exchange**. While larger companies are more organised towards the I4.0 initiatives and pushing its implementation, the necessary effort for data integration in smaller companies is comparatively much higher. Further, a very high risk is perceived in that **only the largest actors in a supply chain or those closest to the customer, retain any economic benefit from data sharing**. Thus, competitiveness in the mind of many SMEs currently comes rather from process improvements for many SMEs as suppliers, while providers of Industry 4.0-technologies are focusing on product improvements. Key requirements of I4.0, such as data-based I4.0 integration or even new business models based on that, are comparably less considered by many SMEs. In general, traditional industrial sectors struggle with the integration of data-based business models and a change of mind-set towards I4.0. Especially process industries struggle to think towards

new, data-driven business models. Further, company workers fear relocation of their jobs, and even cases of not using advanced machine capacities or even sabotage were observed on the shop floor. This **requires substantial requalification of the workforce and adequate addressing of their fears and integrating them into I4.0 implementation**. Regarding data governance, the issue of **data centralisation and sharing** was underlined, which is especially challenging in the multilevel EU governance framework. The **question which data belongs to whom, and who can benefit from it** is challenging if data shall be stored in data clouds. Further, providers of data storage and analytics are often based outside of the EU. Especially Chinese programs, such as “Made in China 2025”, are perceived more openly by the local manufacturers, are seen more as a chance than a challenge, for instance to ‘leapfrog’ from I2.0 to I4.0 directly.

5. SESSION ON INDUSTRY 4.0

Flanders Make (RTO) presented a practitioner's example of I4.0 and W4.0 implementation. In their experience, **EU companies are more focused on product than process innovation**. EU companies are only starting to make a transition from product to production innovation, whereas their Chinese counterparts have historically come from the other side (production to product innovation). In comparison, EU companies are focusing too much on technologies, but not on organisational structure needed for data. Thus, internal data exchange is scattered, then even less possible externally, putting barriers towards product lifecycle management. In practice, there are cases where well performing machines are put in manual operation mode as automated operation is not trusted. However, **shorter lead times are a big opportunity for European SMEs and might lead to relocation to EU** from Asia. Such is, however, only possible if the associated costs are reasonable and could be rooted in the **uptake of industrial trends and then creating the corresponding ecosystem with corresponding Value Chains in public institutions and Universities around**. Further, the potential for European SMEs to **exploit new algorithms for existing machines, predictive maintenance, and augmented reality were underlined**. It was also stressed how the I4.0/W4.0 trends put more focus on **collaboration among people and the human-machine interaction**.

The presentation between the JRC and University of Birmingham showed a range of qualitative and quantitative evidence for understanding of firms' R&D and innovation value chains. The extension of GVCs and GINs observed in the past decades has led to **much less job creation in the US or the EU than in countries like China or India**. Due to the fragmentation of these chains, a large share of activities is not captured by measurable indicators and thus seems underestimated. While eg. alliances between firms and Universities are not new, **relationships are nowadays much more complex and longer term** and the academic system more systematically integrated with these GINs of the private sector. The nature of outsourcing also plays an important role: in sectors such as pharmaceuticals, fundamental tasks are outsourced to Contract Research Organisations (CROs) and become so large in scale that **these CROs have now become critical in drug**

creation processes. Current indicators do not capture this; **the actual R&D of large firm is interdependent with the ecosystem and its organisation.** This leads to an increasing importance of a knowledge policy discussion away from the industrial base towards the ecosystem.

The presentation by DG-RTD showed a policy-view on how to grasp the I4.0/W4.0 challenges. The main policy question is that **the data economy challenges many European values and the EU's social model.** The mission of DG-RTD is to draw attention to R&D&I and turn these into business, growth and jobs. Industry is indispensable to produce the change, and EC-wide initiatives are going on together with DG-RTD, such as on industry 2030 and KETs. Challenges for our balance are the sluggish productivity growth of the past decades and the dematerialisation of the economy, resembling to some point a post-growth society. **New policy narratives where the physical and digital economies meet are necessary.** The main issue then becomes how to translate such narratives into practice. The difference between I4.0, which concerns mainly Supply Chain Management and digitisation of the value chain, and the 4th industrial revolution, which additionally comprises smart materials, KETs, or biotech, was outlined. Also the **true need to decarbonise by 2050 increases the pressure to find breakthrough technologies and find closer links between industrial policy and the circular economy.** This produces closer interaction across the different policy levels, as foreseen eg. in the latest Industrial and Research Policy Communications, and a close link to education and skills policies and frameworks. The I4./W4.0 also requires **policy beyond collaboration** towards addressing which tools are needed specifically for which GVC/GIN and at which governance level.

6. SESSION ON WORKFORCE 4.0

Eurofound then showed the results of a wide range of studies concerning the current I4.0 /W4.0 developments and the potential implications for employment and skills. The main issue is that **the picture is much differentiated:** both on the side of job profiles with the required competencies and on the direction and magnitude of the impact. From the point of view of the individual jobholders, most trends from I4.0/W4.0 are **perceived as increasing (negative) stress and job-insecurity.** Despite many country differences, the levels of self-employment are stable at the EU level. About **half of the self-employed in Europe can be considered to be economically independent and opportunity-driven.** In contrast to that, **about one quarter is characterised by economic dependence, low autonomy and financial vulnerability.** Among self-employed, an emerging business model are "**born globals**", which are very young (and often high growth) enterprises directly addressing the international market. Among these are mostly European SMEs, which have different roles in the global GVCs and GINs. Regarding the digital transformation, there is a **need for further differentiation** in understanding the impact of automation, platforms as intermediaries, and digitisation.

The JRC then presented preliminary results on its ongoing analyses on the future of work and employment. Due to an **incomplete and scattered evidence base**, combined with intertwined trends of automation, platforms, and digitisation, it is challenging to disentangle the global picture into more details. Some examples were presented, e.g. upgrading observed in Poland, or the fact that capital regions absorb the impact of I4.0/W4.0 better than the periphery. Some evidence of a JRC survey on platform workers showed a rather low EU average (2.3%), compared to 4% in the UK. However, 10% of interviewees have provided labour services through platforms at least once. Further, the JRC evidence shows that **salary premiums are decreasing in many EU countries**. Increasingly, **non-cognitive skills explain wage differences**: in the higher earning countries, higher shares of the workforce have sufficient level of digital skills compared to their peers.

Brainport Eindhoven then presented an **example of industrial transformation** within I4.0/W4.0, developing in the past decades. The region has been hosting the headquarters of Philips, which had been a fully vertically integrated company until the 1970ies and then started to disintegrate and create a local open innovation ecosystem. In this ecosystem, the company ASML has grown from a Philips research Spin-Off towards a global market leader for high-precision photolithography systems for the semiconductor industry on its own, with 15000 employees. The last economic crisis has however hit ASML very hard and led them to **find new ways of collaboration because of knowledge development and risk reduction with long-term perspective**. ASML suppliers are managed via an online system and can only have a limited percentage of their turnover directly from ASML so **to increase the resilience of the supply chain and the local ecosystem**. Also, the collaboration between ASML and the University and public sector was outlined. Given the very high number of job applications the company receives, certain profiles that are deemed interesting to the local ecosystem are shared within. Equally, Universities are informed “in real time” about the knowledge needs of the company, in order to stimulate fast updates of curricula.

7. POLICY ROUNDTABLE AND CONCLUSIONS

This section summarises the discussions alongside the presentations and extracts policy conclusions. Regarding the geographic dimension, there is the **need for better understanding the actors in the GINs/GVCs and finer-grained data**. Policy support needs a finer mapping of R&D&I activities across strategic value chains in order to increase the effectiveness of (industrial) innovation policy, also in light of the implications it raises for the (co)location and relocation of companies' R&D&I and production in the EU.

Such data can help in addressing the different regional capabilities needed. A policy **narrative could be drawn towards the development of ICT linked patents**. While the EU missed the first 'ICT revolution', it can benefit from the application of those technologies for the digital transformation in industry. This implies further strengthening technology-specific capabilities of regions in relation to targeted strategic value chains.

Regarding I4.0 and W4.0 implementation at the company level, the **issue of data sharing and who benefits from it has been underlined**. It was also outlined that **not all participants in the GVCs/GINs are similarly vulnerable to substitution**: the more individual companies are based on advanced products and process innovation, the less vulnerable they become. The eventual role of the EU for pushing towards suitable framework conditions, and ways to organise and share data in a way deepening the EU social model was mentioned.

At the company level, the **critical role of upskilling and retraining the workforce were underlined**. Examples of **Chinese companies leapfrogging from I2.0 to I4.0** were mentioned, which was **not attributed to lower labour costs per se but rather a high capacity to integrate into advanced GVCs and GINs combined with high flexibility in the company business models**. So the role and impact of I4.0/W4.0 are a question of perspective: in countries with high wages, they do lead to job displacement via outsourcing or automation, whereas in low-wage countries they are used for upgrading global integration into GVCs/GINs. The impact of W4.0 on the workforce is thus **directly related to the skill level and only an improvement for the highest skilled ones**. Growth at high skill levels can be expected rather in the long than the short run and in new occupations directly related to the Digital Transformation.

It was outlined that the discussion should keep in mind that looking at the new labour market through the eyes of the old labour market might miss the target. In order to fit both society and companies' expectations, **new ways of work need to be found** maintaining overall decent working conditions, a fair level playing field, assuring minimum social standards and avoiding social dumping.

Regarding reshoring, it was observed that the **scissors between cost-based offshoring and reshoring has been closing in the past years**. More advanced companies tend to have higher levels of back shoring because higher automation brings

higher productivity and flexibility, which allows more local manufacturing activities close to key markets and customers. Recent reshoring evidence from Austria points to the fact that this often happens within the firm and the (macro-) regional level. **More important than labour costs are production flexibility, quality and workflow coordination issues.** Much back shoring to Europe currently happens **from within the EU**, often from Eastern Europe, and mainly in the ICT and automobiles sectors, thus not recovering activities from sectors such as textiles or food. New production technologies, such as additive manufacturing beyond prototyping, **might however trigger reshoring** in other sectors than those currently observed. More data on understanding which functions are locally bound and which tradeable would be necessary.

Also **regulation and work within Public Private Partnerships (PPPs)** were outlined as policy measures successfully addressing the I4.0/W4.0 challenges as they create networks, trust and validation. It was mentioned that the high dynamics of I4.0/W4.0 realities provide a challenge to agile regulation.

References

- Birkel, H. S., Veile, J. W., Müller, J. M., Hartmann, E., Voigt, K.-I. (2019). Development of a risk framework for Industry 4.0 in the context of sustainability for established manufacturers. *Sustainability*, 11(2).
- Buhr, D., Stehnken, T. (2018). Industry 4.0 and European Innovation Policy - Big plans, small steps. WISO Diskurs 12/2018, The Friedrich-Ebert-Stiftung, Germany.
- Brynjolfsson, E., Mitchell, T., Rock, D. (2018). What Can Machines Learn, and What Does It Mean for Occupations and the Economy?'. *AEA Papers and Proceedings*. vol. 108. See at <https://www.aeaweb.org/articles?id=10.1257/pandp.20181019>
- Cano-Kollmann, M., Hannigan T. J., Mudambi, R. (2018). Global innovation networks – organizations and people. *Journal of International Management*, 24(2), 87–92.
- Cirillo, V., Rinaldini, M., Staccioli, J., Virgillito M. E. (2018). Workers' awareness context in Italian 4.0 factories. LEM Papers Series 2018/13, Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies, Pisa, Italy.
- Craglia M. (Ed.), Annoni A., Benczur P., Bertoldi P., Delipetrev P., De Prato G., Feijoo C., Fernandez Macias E., Gomez E., Iglesias M., Junklewitz H, López Cobo M., Martens B., Nascimento S., Nativi S., Polvora A., Sanchez I., Tolan S., Tuomi I., Vesnic Alujevic L. (2018) Artificial Intelligence - A European Perspective, EUR 29425 EN, Publications Office, Luxembourg.
- Dosso, M., Potters, L., Tübke, A. (2019). *Distribution of industrial research & innovation activities: an application of technology readiness levels*. Industrial R&I – JRC Policy Insights, European Commission.
- Dosso, M., Potters, L., Tübke A. (2017). *R&D and innovation across global value chains: insights for EU territorial Innovation policy*. JRC Policy Insights - Industrial R&D, European Commission.
- European Commission (2009). *Preparing for our future: Developing a common strategy for key enabling technologies in the EU*. COM(2009) 512 final, {SEC(2009) 1257}.
- European Commission (2010a). *Europe 2020 – A strategy for smart, sustainable and inclusive growth*, COM(2010) 2020 final.
- European Commission (2010b). *A Digital Agenda for Europe*. COM(2010)245 final.
- European Commission (2010c), *Europe 2020 Flagship Initiative Innovation Union*. COM(2010) 546 final / SEC(2010)/ 1161.
- European Commission (2010d), *An Integrated Industrial Policy for the Globalisation Era - Putting Competitiveness and Sustainability at Centre Stage*, COM(2010) 614 final.
- European Commission (2012), *A Stronger European Industry for Growth and Economic Recovery - Industrial Policy Communication Update*. COM(2012) 582 final.
- European Commission (2014). *For a European Industrial Renaissance*. COM(2014) 14 final.
- European Commission (2015). *A Digital Single Market Strategy for Europe*, COM 192 final.
- European Commission (2016). *Digitising European Industry – Reaping the Full Benefits of a Digital Single Market*, COM(2016) 180 final.
- European Commission (2017a). *Investing in a smart, innovative and sustainable Industry - A renewed EU Industrial Policy Strategy*. COM(2017) 479 final.
- European Commission (2017b). *Strengthening Innovation in Europe's regions - Strategies for resilient, inclusive and sustainable growth*. COM(2017) 376 final - {SWD(2017) 264 final}.
- European Commission (2018). *Towards a common European data space*. COM(2018) 232 final Brussels.
- European Commission (2019). *Towards a sustainable Europe by 2030*. Reflection paper https://ec.europa.eu/commission/sites/beta-political/files/rp_sustainable_europe_30-01_en_web.pdf
- Frey, C.B., Osborne, M.A. (2017). The future of employment: how susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, 114, 254–280
- Gereffi, G. (2018). *Global Value Chains and Development*. Cambridge University Press.

- Gereffi, G., Sturgeon, T. (2013). Global value chain-oriented industrial policy: the role of emerging economies. Chapter 14 in D. Elms & P. Low (Eds.) *Global value chains in a changing world*, WTO Publications: Geneva, 329-360.
- Liu, J., Chaminade, C., Asheim, B. (2013). The geography and structure of global innovation networks: a knowledge base perspective, *European Planning Studies*, 21 (9), 1456-1473.
- Moncada-Paternò-Castello P., Coad A., Vezzani A. (2018). "For a transformative industry & innovation strategy" (JRC Science for Policy Insights European Commission – Joint Research Centre. Seville (Spain). INDUSTRIAL R&I - JRC Policy Insights, IRITEC briefs series - Issue # 5; JRC110888 – Seville (Spain), February 2018). ([link](#))
- Müller, J.M., Buliga, O., Voigt, K.-I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting & Social Change*, 132, 2-17. (Müller et al 2018a)
- Müller, J.M., Kiel, D., Voigt, K.-I. (2018). What drives the implementation of Industry 4.0? The role of opportunities and Challenges in the Context of Sustainability? *Sustainability*, 10, 247. (Müller et al 2018b)
- Müller, J. M., Voigt, K.-I. (2018). Sustainable industrial value creation in SMEs: a comparison between Industry 4.0 and Made in China 2025. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 5(5), 659-670.
- NESTA (2017). Anticipatory regulation: <https://www.nesta.org.uk/feature/innovation-methods/anticipatory-regulation/>.
- OECD (2016). *The links between global value chains and global innovation networks: An exploration*, OECD, Paris.
- Ramirez, P. (2018). *Global Innovation Networks: State of the art and issues at stake for GVCs*. European Commission, JRC – GLORIA's project research collaborations.
- Okazawa, R. (2013). Skill-biased technical change, educational choice, and labor market polarization: the U.S. versus Europe. *Journal of Economic Inequality*, 11(3), 321–342.
- Porter, M.E., Heppelmann, J.E. (2014). How smart, connected products are transforming competition. *Harvard Business Review*, 92(11), 64-88.
- UN, United Nations (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. Resolution adopted by the General Assembly on 25 September 2015, http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E
- UN DESA/DPAD (2017). *The impact of the technological revolution on labour markets and income distribution*. Frontiers Issues, July. UN Publications.
- Smit, J., Kreutzer, S., Moeller, C., Carlberg, M. (2016). *Industry 4.0 – Study for the ITRE Committee*. European Commission's Directorate General for Internal Policies, Policy Department A: Economic and Scientific Policy.
- Ulmann, L. (ed) (2017). Industry 4.0: The New Industrial Revolution for Europe. *The European Files*, January 2017, n° 45.

Box. Some definitions

Examples of definitions of Industry 4.0

“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”

“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”

“Industry 4.0 is the combination of new technologies and organization of labor to push manufacturing into a new realm of optimization. It is a trend that focuses on creating smart factories through innovative communication and design between machines and humans.”

Other definitions

Global Value Chains (GVCs): “The value chain describes the full range of activities that firms and workers do to bring a product/good or service from its conception to its end use and beyond. This includes activities such as design, production, marketing, distribution and support to the final consumer.” (<https://globalvaluechains.org/concept-tools>)

Global innovation networks (GINs): “GIN is the more recent term used to refer to the complex webs of internationally dispersed research, development and innovation (RDI) networks” (see Ramirez 2018 for a detailed state of the art)

Business model: “The sum of the value creation mechanisms, value offer, and value capture mechanisms and their links,... Value creation refers to the tasks, which a company performs in order to provide an offer to its customers. In manufacturing organizations, value creation is the sum of the tasks undertaken at own production locations and of the ones performed by suppliers and partners in the business ecosystem. Value capture, also termed as monetization refers to the means, by which a company is compensated by customers and, by which it sustains itself through commercial activity...Finally, the value offer is the assortment of products and services individual to each company and can be conceptually located on a continuum from product-only offers to service-only offers” (Müller et al 2018a)

Sustainable industrialisation: “The term “sustainable” addresses the need to decouple the prosperity generated from industrial activities from excessive natural resource use and negative environmental impacts. It implies that no one is left behind and all parts of society benefit from industrial progress, which also provides the means for tackling critical social and humanitarian needs”. (<https://isid.unido.org/about-isid.html>)

Anticipatory regulation: “...is an emerging method of regulation that is proactive, iterative and responds to evolving markets” (NESTA, 2017)