European Commission

Industry 5.0 and the Future of Work:
making Europe the centre of gravity for future good-quality jobs

ESIR Focus paper

Independent Expert Report

Research and Innovation

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Industry 5.0 and the Future of Work: making Europe the Centre of Gravity for future good-quality Jobs

ESIR Focus Paper

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Introduction: a "perfect storm" for the future of work

Ten years after the seminal contributions of Autor and Dorn (2013) and Osborne and Frey (2013), economists are still struggling to understand how the digital transformation, and in particular Artificial Intelligence (AI), will impact the quantity and quality of jobs in the coming years. The initial focus on the number of "automatable" jobs, which raised the alarm on possible major disruptions and demand shortages in labour markets, was quickly replaced by a more reassuring focus on "tasks": this was based on the assumption that digital technologies such as robotics and AI could only automate certain repetitive, routine tasks associated with existing jobs, and at the same time could create many new tasks for humans, resulting in millions of new jobs (WEF 2020). Researchers gradually highlighted the disproportionate impact of automation on mid-skilled jobs, especially in the United States, which experienced an ongoing polarisation of labour markets (a so-called "U-shaped" development in the availability of jobs), and a corresponding focus on labour and industrial policies on "good jobs" (Rodrik and Sabel 2019; Rodrik and Stantcheva 2021; for Europe, Goos et al. 2011; Brekelmans and Petropoulos 2020). At the same time, the decreasing share of manufacturing in the economy has led scholars to invoke industrial policies that go beyond the traditional focus on manufacturing, a move that has important consequences on skills and education policy writ large. In Europe, especially during the COVID-19 pandemic, the acceleration of digitalisation had a major impact on labour markets, which rather than polarisation show evidence of a J-shaped evolution, and thus the need for more skilled jobs in most sectors of the economy (Piccitto and Oesch 2020; Nchor and Rozmahel 2020).

Over the past decade, authoritative scholars have given rise to a lively debate on the potential impact of new general-purpose technologies such as AI on future jobs. Some researchers depicted a future where AI and related technologies determine a steep rise in productivity, leading to economic restructuring, but not to massive unemployment (e.g. Brynjolfsson 2022). Others have objected that the digital transformation may continue to feature the "productivity paradox" originally identified by Solow (1987) during the early age of personal computing. By observing the main channels through which labour can be affected by technological change, scholars such as David Autor have shown that over time, automation has become gradually less labour-augmenting, and more labour-displacing (Autor and Solomons 2018). Other scholars have argued that, in the absence of proactive industrial policy measures, firms will be led to replacing humans with digital technologies even when this leads to an overall reduction in quality, to pursue significant cost reductions, in what has been termed "so-so" automation (Acemoglu and Restrepo 2019).

Today, three years after the COVID-19 pandemic has massively impacted the economy, the scholarly perspective on the future of work seems to have changed again. On the one hand, the acceleration of the digital transformation caused by the transition to remote telework and the severe economic distress experienced in many labour-intensive sectors has accelerated labour replacement, creating the preconditions for a loss of both quantity and quality of jobs. The geopolitical tensions that have accompanied the pandemic have, in turn, led countries to conceive of "re-" or "friend-shoring" policies, which require employers to increasingly face higher labour costs, and thereby greater incentives to automate labour. This process, in turn, is being accelerated by the pace of the digital transformation, which caused the emergence of a new paradox: many economies face at once the prospect of rising unemployment in traditional sectors, and a stunning skills shortage in IT-intensive sectors. Furthermore, the war in Ukraine and the vibrant re-emergence of both security and energy-related imperatives completed the picture of a world in a dangerous balancing act between "poly-crisis" and "permacrisis" (ESIR 2023), a situation in which the job dimension can easily be superseded by shorter-term emergencies.

The final blow to the established debate on the future of work was given by the dramatic acceleration of innovation in the domain of AI, in particular with the emergence of generative AI systems such as ChatGPT, Bard, Llama and others. The ability of these systems to process enormous amounts of information and convert them into an impressively accurate emulation of cognitive human tasks creates new opportunities for automation as well as new challenges for policymakers. A recent study by the U.S. Council of Economic Advisors and the European Commission (TTC 2022), produced in the context of the Trade and Technology Council, marked this emerging paradigm shift in the analysis of the future of work by observing that AI will be able to automate, besides many routine tasks, also non-routine tasks that were previously thought to be "safe"; and that the current lack of concrete evidence of the aggregate impact of AI on the labour force (Acemoglu et al., 2022) "could lower our sense of urgency to understand its impact on work, even when such effects appear likely in the future". In other words, the two institutions portray a "perfect storm" for the future of work, caused by a mixture of technological evolution, geo-economic trends, competing urgencies, and political short-sightedness. These findings were further backed by recent research showing the enormous potential of generative AI systems to replace tasks in the workplace: a paper by OpenAI researchers recently found that around 80% of the U.S. workforce could have at least 10% of their work tasks affected by the introduction of large language models (LLMs), while approximately 19% of workers may see at least 50% of their tasks impacted. Furthermore, access to an LLM could lead to faster completion (at equal quality levels) of about 15% of all worker tasks, a percentage that could rise to 56% if software and tooling built on top of LLMs are accounted for. The latest report on the future of work by the World Economic Forum showed that employers estimate that 44% of workers' skills will be disrupted in the next five years; and that 6 in 10 workers will require training before 2027, whereas only half of the workers are seen to have access to adequate training opportunities today.

Against this background, the future of work is going through a perfect storm, made at once of increasingly warning signs of labour displacement and skills shortage, and equally worrying tendencies to discard labour disruptions as less important than other emerging problems, including those related to economic competitiveness and strategic autonomy. To the contrary, Harvard economist Dani Rodrik rightly observed that while "climate change is the biggest threat to our ecological environment, labour market shocks are the biggest threat to our social and political environment." In this brief, we unpack many dimensions of the future of work debate, placing them in the context of current EU industrial and innovation policies. We focus in particular on the debate on industrial transformation, under an Industry 5.0 lens (as will be explained below); as a result, we do not directly tackle equally important issues such as the future of work in the public sector.

Section 1 below argues that the reference paradigm for industrial transformation, the so-called Industry 4.0, takes insufficient account of the jobs and skills dimension as well as the related societal impacts; and that similarly, the current emphasis on "net zero" does not place sufficient emphasis on the jobs emergency. We thus propose that the EU adopts a comprehensive Industry 5.0 strategy, aimed at making systemic industrial transformation a protagonist of future resilience and sustainability, rather than an obstacle on the way to a more prosperous future. This Industry 5.0 approach has to include the future of work as an essential dimension of future sustainable development, at the same level as other essential goals such as protecting climate and biodiversity and, more broadly, ensuring long-term resilience. We also propose that this approach be accompanied by strategic foresight and horizon scanning, given the uncertainty associated with the evolution of industry (and work) in the coming years. The long-term future of work, it must be recalled, entails too many uncertainties for any safe projection (see *e.g.* the Millennium Project).

Section 2 proposes a step-by-step approach to mainstreaming jobs in EU industrial policy, both at the EU and at the regional level, based on foresight and backcasting. This approach would help policymakers consider key issues such as: (i) *"What future"*, or better: what alternative futures may emerge, with different consequences for the future of work, and how to account for increased uncertainty and the poly-risk world when planning for the future of work; (ii) "*What jobs*" will emerge in Europe, in terms of quantity, quality and specialisation; and (iii) "*What skills*" will be needed, especially if a human-centric approach to the digital transformation is adopted, calling for complementarity between humans and machines, and the primacy of the former over the latter. This will lead us beyond the traditional emphasis on "STEM" and coding, towards a broader recognition of critical thinking, social and soft skills, as well as domain knowledge, creativity and imagination as distinctive traits of future human occupations. We also propose methodologies to map Europe's relative technological specialisation and the potential to create future jobs, in a way that accounts also for the regional specificities of the EU territory; and argue in favour of mainstreaming the creation of "good jobs" in all EU policies.

1. The need for a paradigm shift: from the Fourth Industrial Revolution to Industry 5.0

Our first and foremost consideration, in a paper dedicated to industrial policy and the future of work, is that the current Industry 4.0 approach is unable to ensure the salience of job creation that should be given in future EU policies, as observed in Section 1.1 below. In Section 1.2 we then argue in favour of embracing an Industry 5.0 approach, based on a human-centric, resilient and sustainable vision of future industrial transformation. Importantly, this requires a specific approach to the definition and pursuit of job quality, which we outline below, in Section 1.3.

1.1. The Industry 4.0 paradigm, the twin transition and the Net-Zero approach do not account for "good jobs"

The past decade has been characterised by a growing emphasis on the "fourth industrial revolution" as the dominant framework for government policies in the context of the pervasive digital transformation of industry sectors. The impact of digitalisation was seen as potentially boosting industrial productivity, thanks to the deepening of digital technologies (in particular, connected objects and cyber-physical systems) in all aspects of manufacturing. Prominent international organisations such as the OECD and the World Economic Forum have championed the Fourth Industrial Revolution (4IR) paradigm by advocating changes in government policies aimed at matching the speed of technology developments (e.g. agile regulatory governance, see OECD 2021 and 2022; WEF 2020); as well as investments in more decentralised industrial value chains, thanks to the advent of edge/cloud/IoT architectures and a widespread application of AI at the workplace. During the COVID-19 pandemic, given the changing geo-political context, this theoretical framework was also used to advocate greater resilience in value chains, and the possibility of investing in re- or friend-shoring of production to boost productivity and reduce dependency on foreign, single sources of supply. Yet, given their almost-exclusive focus on technology, Industry 4.0 policies ended up treating both the sustainability and the employment challenges more as afterthoughts than essential pillars of government industrial policy, as already observed by ESIR.[1] While scholars and international organisations that have strongly championed the Industry 4.0 approach have promoted an optimistic narrative for both climate change (see Suryadi et al 2022) and employment (Fox and Signé 2022), in reality, the Industry 4.0 framework seems insufficient to underpin the systemic industrial transformation imperative that most nations, including European countries, face today.

In Europe, the Industry 4.0 approach has gradually been coupled with a vision of industrial transformation aimed at achieving the so-called "twin" (green and digital) transition. However, even if framed under a vision of sustainable competitiveness, this approach provides limited assurance when it comes to the creation of good-quality jobs. And even if the twin transition is also presented and implemented via a just transition mechanism, this element is intended as a compensatory action for those regions that will stand to suffer the most from the closure of fossil fuel plants, rather than a systemic, transformative strategy to mapping and promoting the skills and jobs that are functional to the future EU industry. Furthermore, the impact of the two pillars of the twin

[1] The ESIR group has already presented its overall views on Industry 5.0 in a policy brief, which includes a long list of action items that would ensure coherence across EU policies, and a real mainstreaming of the pillars of Industry 5.0 in a wide range of policies at different levels of government, including EU R&I policy (e.g. the missions), the industrial strategy, the European Green Deal, employment policies and national policies enacted in the context of Next Generation EU.

transition on future jobs is hard to anticipate. On the one hand, there is no certainty that the green transition will create a very large number of jobs in Europe in the years to come, especially if the EU fails to pave the way for substantive public and private investment, as well as the necessary skills. Available (yet rather tentative and controversial) evidence suggests that so-called "green jobs" tend to provide good quality employment and pay relatively higher wages than non-green jobs, especially for middle- and low-skilled workers, and are also at lower risk of automation (Valero et al. 2021). A recent JRC foresight study on green jobs foresees a net increase in jobs in the EU of up to +0.45% by 2030, achieved through a realignment of employment across sectors that will entail the reduction of employment in fossil fuel intensive and high greenhouse gas emitting economic activities. In reality, the green transition seems poised to negatively affect several regions: bold policies, experimentation with region-specific approaches and *ad hoc* initiatives through EU missions are needed to address job loss and bring novel solutions.

On the other hand, the digital pillar of the twin transition has so far failed to trigger a sustainable and resilient industrial transformation; rather, it led to rising economic inequality, tensions in the labour market and an overall deterioration of job quality, as many jobs are being re-intermediated by digital labour platforms. The emergence of AI as a "new competitor" for human labour in addition to capital inevitably weakens the bargaining power of workers, especially those that perform tasks that are at high risk of automation (as explained, not only low-skilled, and not only routine tasks). Furthermore, the use of AI in recruitment and in the workplace already became widespread in many countries (TTC 2022), with policymakers struggling to find suitable policy measures to contain the risks that these practices inevitably create for the protection of human rights, and specifically workers' rights. The resulting, dramatic trade-off for many workers is either to accept an ever-lowering bargaining power and thus a reduced ability to capture the value of their work in the form of decent job quality; or to face the risk of being replaced by other factors of production. EU policymakers should therefore find suitable ways to pursue the twin transition in a way that promotes the creation of a sufficient number of good jobs. This imperative refers both to the quantity of jobs, as well as their quality.

In summary, the EU does not currently have a comprehensive strategy for the systemic transformation of the economy, which includes adequate consideration for the quantity and quality of future jobs. The recent launch of the Net Zero Industry Act and of *ad hoc* "academies" to create the necessary skills is a promising move; however, even this welcome step fails to give sufficient importance to the issue of job creation and skills nurturing. Furthermore, Europe's ambition to become a world-class destination for green investment, which in turn would enable the creation of new jobs, seems to have been frustrated by the revival of industrial policy in competing destinations such as the United States, where several policy measures (including most notably the Inflation Reduction Act) are attracting investments in clean energy with the promise of tax credits and comparatively lower regulatory burdens.

1.2. Towards Industry 5.0: a primer for promoting "good jobs"

While Industry 4.0 and the current twin transition policies fail to put humans at the centre of the industrial transformation, the Industry 5.0 approach places a stronger emphasis on "good jobs" since it features a human-centric, resilient and sustainable approach to industrial transformation. Adopting this conceptual framework has important consequences for the future of industrial and innovation policy in the European Union. Below, we focus on the three main pillars of the Industry 5.0 paradigm, as applied to the future of work and skills policy: human-centricity, requiring due attention to human-machine cooperation and a redefinition of jobs quality; resilience, which implies a new approach to skills, industrial organisation and the adoption of decentralised forms of governance; and sustainability intended in its economic, social and environmental dimensions.

1.2.1. Human-centricity

Human-centricity entails that the deployment of new technologies in the workplace, from robotics to Artificial Intelligence (AI) and the Internet of Things (IoT), is not taken as an ultimate goal, but rather as a means to empower and (ethically) enhance workers, thus generating greater productivity and well-being on the workplace through the meaningful interaction of humans and machines. In other words, human-centricity requires acknowledging that not everything that "can" be automated "must" be automated; and that automation should lead to human flourishing and the empowerment of workers in the workplace, rather than the replacement of humans with digital artefacts. As a result, the focus of policymakers should fall on incentivising human flourishing through: (i) the development of trustworthy technologies, *i.e.* technological solutions that are compatible with fundamental rights and the rights of workers in the workplace (applicable at the whole supply chain level through due diligence obligations); (ii) a deeper inquiry into the determinants of well-being on the workplace, and including in digital labour platforms and remote working arrangements; and (iii) investment in the complementary skills that will allow workers to enhance their productivity, liberate themselves from repetitive tasks, and focus on the more intellectually stimulating ones.

This triple effort should inspire priority-setting in various policy domains. Yet, this is easier said than done, especially if no concrete steps are taken to invert current trends in industrial transformation. One such trend is the ongoing, widespread application of algorithms to organise, monitor and even sanction workers, leaving very little space for social dialogue. Even more worrying, the diffusion of business models such as those of digital labour platforms (see. e.g. ILO's WESO 2021 report) seem to be fundamentally incompatible with such a view and hardly allow for any solution to the problem of meaningful human-machine cooperation. Current efforts, including the proposed rules aimed at improving the conditions of platform workers, are unlikely to provide structural solutions to this problem. Against this background, current policy initiatives aimed at encouraging or even mandating trustworthy AI uses could and should become the basis for a new approach to human-machine cooperation on the workplace. Human-centric principles such as the respect for human agency and self-determination, transparency, human oversight and fairness principles have been included in the EU requirements for trustworthy AI already in 2019; and are foundational in the proposed AI Act, which includes uses aimed at monitoring and recruiting workers in the list of high-risk AI applications, as such subject to rather strict regulatory requirements.

Will this be enough? Probably not, if the empowerment of workers will remain an afterthought or a regulatory remedy. Rather, incorporating human-empowering forms of industrial transformation in the design of industrial policy, thus mainstreaming "good jobs" and adequate skills in the definition of policy and investment measures, is the only way to guarantee meaningful human-machine cooperation in the future, and even more in the age of generative AI systems. This entails, *i.a.*, the identification and promotion of meaningful forms of human oversight (such as humans "in" or "on" the loop), coupled with the advancement of skills that enable humans to oversee the functioning of machines fully and effectively, rather than delegating to them the ultimate decision-making role. Moreover, ensuring that representatives of workers have access to (or even co-design) the AI systems that are used to monitor workers' performance is likely to be a more effective remedy in terms of empowerment and job quality (AlgorithmWatch 2023).

Finally, a deep inquiry is needed to continuously monitor the evolving impacts of generative AI systems on the world of work. The possibility to replace a large portion of the workforce through the use of large language models is concrete, and requires deep changes in the education system, in life-long learning and on-the-job training, and even in the organisation of work. For example, powerful generative AI systems could easily be integrated into "superteams", and be trained by workers to become a valuable team-mate, able to become the living memory and ongoing virtual cognitive assistant of its team-mates. Legislators should also get ready for the possibility that sufficient jobs, at least in transition periods, will not be demanded in existing sectors, and compare forms of universal basic income with an overhaul of welfare policies, allowing for people to work a reduced number of hours (e.g. 3-day working week) to enable full employment.

1.2.2. Resilience and the Role of Skills

The resilience pillar of Industry 5.0 calls for *ad hoc* policies, aimed at ensuring that individual organisations, as well as whole value chains, are put in the condition to thrive despite unforeseen shocks. Such shocks are likely to become more frequent, and less predictable over time, as the world ushers into an age of “poly-crisis” (ESIR 2023). They are also likely to become more diverse, with technology, natural (human-induced) disasters and geo-political paradigm shifts becoming tightly interconnected.

In this respect, scholars have observed that more decentralised and diversified governance models tend to be more resilient than very centralised ones, since they avoid the “single point of failure”, and are more able to reorganise themselves whenever disruption occurs in parts of the system. While this has important consequences for innovation and technology in general (e.g. more decentralised architectures such as edge networks are more resilient and less prone to failure; federated learning can mitigate the risk of privacy intrusion, etc.), they have equally important impacts on the role of workers in supply chains.

Resilience requires enhanced human capital investment to supervise and oversee machines and mitigate the risk of their malfunctioning, at the same time making the most of their productivity-enhancing features. Such investment should be focused on complementary skills, through a vision of technology that augments, rather than replaces, human intelligence; relatedly, anticipatory policies and research should address future challenges related to technologically augmented humans entering the job market. Moreover, resilience requires that human capital is not concentrated in one part of the supply chain, but distributed at the edges: the ability of a supply chain to reorganise itself in times of disruption, or rapidly shift modes of production or distribution, is directly dependent on the level of human intelligence available to all nodes of complex value chains.

In summary, incorporating resilience objectives has significant consequences for the overall design of industrial policies, particularly when it comes to risk management in the age of poly-crisis. A resilience focus in Industry 5.0 requires the use of foresight to anticipate disruptions in markets and supply chains, as well as the need for new skills following geo-economic and technology shocks; the prioritisation of versatile skills, which could be applied to new uses in case of a sudden need to adapt; the constant re-training of workers on the job; the diversification of supply chains; and the need to build intelligence at all stages of production and distribution.

1.2.3. Sustainability from an economic, social and environmental perspective

The sustainability pillar of Industry 5.0 must be intended in its economic and social dimensions, in addition to the environmental one. Here too, more decentralised, inclusive and human-centric business models seem to feature key advantages over centralised, purely profit-motivated ones. Several elements can be highlighted. First, socio-economic sustainability requires a fair distribution of value: this in turn implies adequately rewarding value creation and investing in human capital to empower workers throughout the value chain. Second, socio-economic sustainability also requires restoring and updating workers’ rights, by adding new layers of protection and empowerment especially when it comes to technology. Policy implications include the need to protect the mental health of workers in highly automated and distributed workplaces; measures aimed at reimagining social dialogue in environments characterised by algorithmic governance and surveillance; action to reward businesses and supply chains that prioritise workers’ well-being and representation (including through sustainable corporate governance and adequate ESG indicators); skills policies that ensure that businesses can effectively avail of appropriate human capital in times of quick transformation; and, on the EU side, transition pathways that, along with mapping future technological developments, inspire also concrete industrial policy measures based on a broad understanding of well-being, way beyond pure productivity.

More generally, from a future of work perspective, sustainability calls for investing both in the quantity and the quality of future jobs. At the same time, the quest for "good jobs for all", or full and decent employment as pursued by SDG 8, is likely to be frustrated by the future obsolescence of established professions, as well as by the shrinking demand for labour in many manufacturing sectors. Importantly, authoritative economists have pointed out that manufacturing jobs are unlikely to be able to provide sufficient jobs opportunities in the future, given the sector's shrinking weight on total value added, and that a proactive strategy for good jobs should incorporate services, as well as new (or currently unaccounted) forms of employment. The focus on services is present in the European Commission's 2021 Communication on the update of the industrial strategy, with specific reference to the long-awaited completion of the Single Market. The Commission observes that "the services sector deserves particular attention because of its size, the interplay with goods and its cross-ecosystems nature". That said, the link between industrial ecosystems, the data strategy and the future data-driven services creation appears to be weak at best in the current EU plans, as well as in national resilience and recovery plans.

The relative lack of attention to service jobs related to specific industrial ecosystems is visible also in the recently launched Net Zero Industry Act, and in the accompanying Commission Staff Working Document on "Investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity". Much in the same vein, when publishing the "transition pathway" for proximity and social services, the Commission argued that both the circular economy objectives and the digital transformation will create enhanced demand for services provided by local cooperatives and social entrepreneurs, yet that the latter entities are very often ignored or side-stepped in the planning of future systemic transformation. A comprehensive strategy for jobs should thus try to include the significant opportunities that will be generated for value-added services related to (or cutting across) industrial ecosystems.

A human-centric, resilient and sustainable approach to industrial transformation requires adequate attention to future service jobs, as well as user-centric business models in digitally transformed sectors. For example, digitally transformed agriculture requires adequate community-based data stewardship services, and related IT solutions aimed at empowering smallholders and larger companies in sharing resources and reaping the value of their production over time, avoiding the problem of "value capture" (Mazzucato 2019; UNCTAD 2021). Digitally transformed governments can act as platforms (GaaP, see e.g. the Estonian X-Road), which small and medium-sized enterprises can leverage to obtain access to data and infrastructure that enables them to offer value-added services. Key new EU initiatives such as the Data Governance Act, the Data Act and the Digital Markets Act open up new opportunities for leveraging data "for good", as well as new business models aimed at managing and reusing data in a more user-centric way. The Data Strategy, and the related Data Spaces (including the GAIA-X project), incorporate a user-centric dimension that may usher into a proliferation of services at the ecosystem level. And the data space for skills, currently in the making, can become a promising match-making platform, provided that adequate skills are available in the marketplace. In a nutshell, the potential for the data economy to create the preconditions for good jobs in the services sector must be explored in depth in the coming years; at the same time, it requires complementary initiatives in terms of foresight and the promotion of new, updated skills.

Moreover, a full and decent employment strategy for Europe requires tackling additional challenges and opportunities. Among the challenges, of utmost importance are the low participation of women in both green and digital sectors, which requires adequate policies in education, as well as proactive measures aimed at closing the gender gap; the emerging shortage of IT and data stewardship skills in strategic sectors, which may limit the extent to which future European SMEs will be able to capitalise on the enhanced availability of data for new business models; and the need to reward unpaid work, including both domestic care work as well as payments for ecosystem services, which are projected to be in high demand as the European population ages, and climate conditions deteriorate. Among other opportunities, is the possibility to liberate humans from mundane and repetitive tasks thanks to advances in technology, and offer them new prospects for creative thinking, for example in cultural, artistic, crafts and humanities-related specialisations.

1.3. What is a "good job"?

To pursue "good jobs", it is of utmost importance that EU institutions carry out a deep reflection on what job quality means. What is a good job? Several institutions publish periodic reports with data related to job quality. These include the ILO's decent work indicators (connected to SDG 8); the OECD Job Quality Framework; the UNECE measurements on quality of employment; and the ILO/Eurofound Working Conditions Monitoring Framework. In the U.S., measures include the U.S. Private Sector Job Quality Index.

In Europe, Eurofound (2021), a European agency dedicated to the world of work, measures the evolution of job quality in the Union along seven dimensions, as shown in Figure 1. These dimensions, with broadly echo the ones measured by the OECD and the overall description of "good jobs" given by Rodrik (2019), are mostly objective and static (except for the "prospects" one, which incorporates elements of security and career progression). Accordingly, while Eurofound reports mostly positive developments in job quality in Europe over the past decade (except for the persisting gender segregation), surveys that incorporate the subjective dimension, such as Gallup (2022), reveal that the level of job satisfaction is much lower in Europe than in other parts of the world, including the United States and Canada.

Figure 1 – Eurofound's dimensions of Job Quality

Broadly speaking, job quality can be measured along two dimensions. On the one hand, the definition can be static, i.e. descriptive of the current working conditions including the career prospects; or more dynamic, *i.e.* compatible with future human capital development and re-training. This more dynamic nature of future jobs also refers to the possibility for job holders to gradually upgrade their skills in their current position, finding increasingly attractive and satisfactory job opportunities. On the other hand, the quality of a job could be seen from the perspective of the individual condition of the job holder ("micro" perspective); or by considering whether the sector in which the job emerges is compatible with the EU's medium- to long-term industrial transformation plans ("macro" perspective). This double perspective on job quality allows for a more strategic analysis of job quality in the EU. By adopting it, it is possible to conclude that there can be "good" jobs emerging in "bad" sectors (for example, coal-intensive sectors); as well as "bad" jobs emerging in "good" sectors (e.g. wind energy).

Despite inconsistent and sometimes contrasting views inside EU institutions, it seems increasingly clear that the European Union's approach to good jobs aims to go beyond the static observation of the individual condition of the worker, by focusing on human flourishing and gradual upgrade of human capital; and also on the extent to which the sector and specific occupation where the job emerges are consistent with the EU's long-term goals in terms of competitiveness and sustainability. In this respect, the EU aims to create neither "good" jobs in "bad" (e.g. environmentally unsustainable) sectors; nor "bad" jobs in otherwise "good" sectors. The quest is thus for good jobs in good sectors, i.e. jobs that entail satisfactory conditions from a static and dynamic perspective, in sectors that are economically, socially and environmentally sustainable. A perfectly decent job in a carbon-intensive industry, in this respect, is not the type of good jobs the EU should be seeking to create; likewise, a mentally stressful, precarious, badly paid job in an environmentally friendly industry sector should be seen as equally undesirable.

Against this background, ESIR is convinced that Europe has very solid foundations, yet an incomplete policy framework, for the creation of good jobs in strategic sectors in the years to come. Europe is often depicted as a laggard in innovation and an inexorably ageing society, unable to keep the pace of technological developments on a par with other superpowers such as the United States or China. If anything, Europe often gets credited with the ability to shape global rules and standards, thanks to its relentless legislative and regulatory activity in several sectors, including emerging technologies (the so-called "Brussels effect"). However, just as the latter virtue is often exaggerated and excessively relied upon (Renda 2022), the former appears equally extreme. When it comes to creating future jobs and offering a quality of life to the workers of the future, Europe has the opportunity to become a world leader: it just needs to realise its potential and adopt an *ad hoc* strategic framework which coherently places good jobs at the forefront of EU policymaking and spending priorities. Below, a possible framework for more comprehensive and systematic incorporation of good jobs in EU industrial policy is presented.

2. Towards a coherent strategy to combine the twin transition with systemic industrial transformation and good jobs

There has been no shortage of EU initiatives on industrial policy, research and innovation funding, as well as jobs and skills over the past few years. Yet, the constantly changing environment in which industrial ecosystems will develop over time calls for a more coherent, agile strategy based on evidence and foresight, as well as with a clear identification of the "North Star" Europe aspire towards. Below, we offer a five-step strategy that crosses the boundaries of competence of various European Commission DGs, and as such requires a whole-of-government approach at the EU level, as well as making the most of the EU's poly-centric governance when locating possible job opportunities and matching them with *ad hoc* skills. This strategy is based on five key steps, which entail several activities and a high degree of policy coherence. They should be read as deeply interrelated, and (especially steps 2 to 5) iterative.

Step 1. Define the "North Star"

There can be no coherent industrial transformation strategy without clarity on where the EU wants to land in terms of its future economy and society. Over the past three decades, however, the EU has struggled to define its North Star, choosing very different frontiers from the Lisbon strategy in 2000 ("the most competitive and dynamic knowledge-based economy by 2010); to a revamped partnership for jobs and growth in 2004; the Europe 2020 agenda in 2010, and the incomplete mainstreaming of the Sustainable Development Goals in EU policy since 2015. The SDGs have then become the basis of the Horizon Europe programme and a feature of the European Semester, though not as prominently as originally announced; and feature prominently in some (yet not all) external action documents, such as the new EU Global Health Strategy and the Foreign Affairs Council Conclusions of June 2021. At the same time, core EU policies for the Single Market focus on a rather different set of objectives, including "sustainable competitiveness", and "competitive sustainability", as well as the twin transition. Besides setting goals in terms of sustainability, the past three years of the COVID-19 pandemic also brought new overarching goals, such as technological sovereignty, open strategic autonomy and the consequent reduction of Europe's dependency on (single) non-EU sources of supply for critical inputs, such as energy sources, raw materials and semiconductors. More recently, also as a response to the U.S. Inflation Reduction Act, the EU industrial policy veered again, this time towards a "net zero" industrial plan and an emphasis on economic security.

In the view of ESIR, this vision should place human and planetary well-being at the centre, and be based on a "people, planet and prosperity" view that incorporates the existing trade-offs between short- and long-term goals, as well as the economic, social and environmental boundaries that should be subject to constant monitoring, and never be crossed. In other words, just as "planetary boundaries" have been identified in the climate literature and have become the basis of a consistent stream of scientific literature (Rockström et al, 2009), economic and social boundaries should also be identified, in a way that will later enable a balanced approach to sustainable development. A first attempt in this direction, which will deserve further elaboration is the resilience dashboard (ZOE Institute and the Club of Rome). A broader set of boundaries, including economic and social ones, would allow for the proper inclusion of key elements such as competitiveness, economic security, and individual and societal well-being, alongside climate- and biodiversity-related dimensions. Defining a comprehensive framework encompassing people, planet and prosperity would also be in line with recent national initiatives aimed at building indicators of well-being, as well as a long-term strategy aimed at preserving the so-called "four capitals" (economic, human, social and natural).

We claim that the development of this comprehensive framework and frontier should be a key foundational task of the next European Commission, in view of defining the North Star that should guide all medium-term measures such as industrial and R&I policy, as well as the regulatory policy to be adopted and implemented in the coming years (under a so-called "double backcasting" approach, see Ashford and Renda 2016).

Step 2. Build a coherent vision for the systemic transformation of Europe's industrial ecosystems

Once the North Star is defined, policymakers should identify which mix of innovation and industry specialisation is most likely to help Europe achieve the desired goals. This task resembles, to some extent, the current practice in DG GROW of defining transition pathways for industrial ecosystems, and existing attempts at goal-based strategies in the EU (e.g., the Green Deal). However, such endeavour should be changed in at least two ways. First, it should not be based on a single vision of the future: rather, it should account for the condition of poly-crisis in which policymakers have to choose their way forward in contemporary times. This implies that policymakers identify, for each industrial ecosystem, a set of alternative futures based on both endogenous and exogenous variables; choose which futures potentially make the greatest contribution to the "North Star"; and apply risk analysis and management to appraise the alternative scenarios' vulnerability to potential future shocks.

Second, "transition" pathways should be interpreted as "systemic transformation" pathways, aimed at developing industrial ecosystems that are human-centric, resilient and sustainable, and contribute to the longer-term goal of people, planet and prosperity as described under Step 1 above. Within each systemic transformation pathway, the role of jobs and future skills should be central.

A sequence of potential steps in this respect could be the following:

- Step 2.1: Identify relevant industrial ecosystems for the future EU industry, including both manufacturing and services.
- Step 2.2: Within each ecosystem, map possible/plausible alternative systemic transformation pathways.
- Step 2.3: Stress-test alternative scenarios for industrial ecosystems based on possible future shocks, including the megatrends identified by the JRC and possibly other significant risks on the horizon.
- Step 2.4: identify the compatibility and synergies between transformation pathways across industrial ecosystems.

Implementing these steps would allow the EU to assess its innovation and competitiveness potential on global markets, and at the same time consider the technology mixes that are most likely to lead the EU towards its North Star. In order to perform a full assessment, the Commission will have to proceed to a mapping of Europe's relative specialisation in essential technologies, and in particular, those related to the twin transition.[2] Figure 2 below shows the ecosystem of technologies mentioned in the EU taxonomy, such as solar energy, wind turbines and nuclear energy; an ecosystem of digital technologies such as AI, cybersecurity or IoT; and the interactions between these two ecosystems.[3] Links between technologies represent their degree of "relatedness" as derived from how often they tend to be combined to create new inventions.[4] It is interesting to note that some of these technologies act as strong bridges between the green and digital transition. Smart grids, for instance, tend to have a very central position connecting solar energy, batteries or transport, but also cybersecurity, the Internet of Things and cloud computing. Nuclear energy is also strongly linked to both green (i.e. hydrogen) and digital technologies (i.e. autonomous robots). Other technologies, such as carbon capture or augmented reality tend to cluster and do not span both ecosystems.[5]

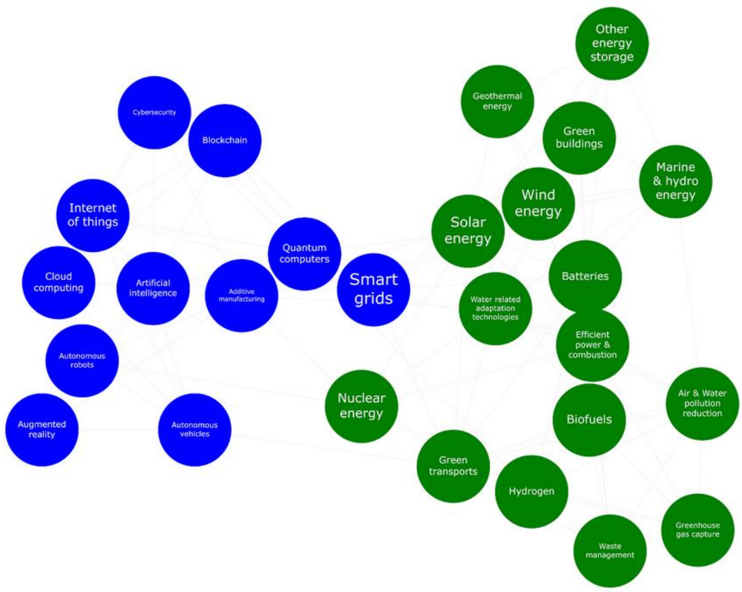


Figure 2. The twin transition space (Source: Balland et al. 2023)

When looking at relative technology specialisation, an analysis of patent data (see Annex 1, and for an interactive visualisation visit this address) indicates that European countries (understood as

[2] There is no consensus or official texts on what the twin transition technologies precisely are. The taxonomy presented in this report is meant to be illustrative and is a way to open a EU-wide debate on which investments should be prioritized to lead the twin transition.

[3] The data comes from patents published under the Patent Cooperation Treaty (PCT).

[4] See Balland et al. (2022) for a description of the methodology used to measure relatedness. Balland, P.A., Broekel, T., Diodato, D., Giuliani, E., Hausmann, R., O'Clery, N. & Rigby, D. (2022) The new paradigm of economic complexity, Research Policy, 51 (3): 1-11.

[5] An interactive visualisation version of the transition space can be explored at this address.

the group composed of EU27, the UK and EFTA countries) are leading the development of technologies for the green transition.[6] From 2016 to 2021, Europe has produced a whopping 30% of all green inventions worldwide. Japan comes second, with 21%, followed by the US (19%) and China (13%). The European dominance is especially strong for domains such as green transports (41%), biofuels (37%) and wind energy (58%). The production of solar energy technology or batteries is more evenly distributed among the largest and most innovative countries. As shown here, Europe has managed to maintain a fairly stable position in the green transition since 2004 (figure 4). We can observe a slowdown during the 2008 financial crisis, but innovation has been relatively stable since 2014. This is remarkable, in the sense that this stability happened despite the meteoric rise of China. In less than 20 years, China increased its production of green patents by almost 20x. The main loser in terms of proportion is the United States, from almost 30% to about 20% now. Japan is also on a declining trend since the 2008 financial crisis.

Europe also shows strong innovative capabilities in the digital transition, but clearly not as much as in the green transition (again, see Annex 1 and for an interactive graph, here). The clear leader in the digital space is the United States, with 38% of digital patents coming from inventors located in the US. China comes second with 22%, closely followed by Europe (19%) and then Japan (10%). AI is an area where EU investments are particularly needed, with only 14% of the patents coming from Europe, as opposed to 38% and 20% for the US and China**.** Europe, however, leads in additive manufacturing (37%), and autonomous robots (26%) and is on par with the US and China when it comes to autonomous vehicles. The dynamic analysis of the digital transition leadership (see here) gives a very different picture. In this case, the early 2000s' was divided between the United States and Europe, with a clear advantage for the US. Since then, the relative performance of Europe has shrunk from 30 to less than 20%.

In the context of a future Industry 5.0 strategy, technology relatedness should be mapped against future industrial ecosystems, in a way that unveils Europe's ability to promote innovation and create jobs where needed, and functional to the EU's overall long-term "people, planet and prosperity" strategy. At the same time, it must be recalled that relative technological advantage or specialisation is unlikely to be the only criterion used to select the ecosystems and innovations to prioritise in future EU R&I and industrial policy. Several considerations will have to be added to the pure analysis presented above.

First, relative technology specialisation and technology relatedness are retrospective, being based on the analysis of patent data. Horizon scanning is an essential complement of this analysis and can unveil cases in which swift competition from other countries could quickly undermine Europe's leadership, as can be the case of clean energy sectors due to rising competition from China, and enhanced investment in the United States. Keeping track of the changing competitive landscape is therefore essential to plan future investment (this could be done as part of Step 2.3, as a stress-testing methodology), and this ongoing monitoring activity can be entrusted to the JRC or DG GROW. Technology foresight can also help policymakers anticipate areas in which a strategic advantage and a degree of autonomy will be essential: these may include emerging technologies in domains such as quantum computing, cryptography and synthetic biology.

[6] Albeit useful and very often used, patents are one out of several indicators that measure innovation, and do not necessarily offer insights on innovation diffusion or on the relative market value of innovation. There are many other indicators available, and the data on green publications and green trade, for example, show that the EU is in some technologies not as strong as indicated by patent data, in particular in comparison with China. On the other hand, these indicators focus on technological innovations. With social innovations and innovations below the radar becoming more important, it is increasingly necessary to look for new indicators which describe e.g. strategies such as sharing or life-time extension, or the role of material consumption for wealth creation. However, it seems also plausible to assume that digital technologies and digital competences will play an important role in moving towards sustainable consumption and innovations below the radar.

Second, the analysis of Europe's relative technology specialisation should be coupled with an analysis of potential technology mixes entailing partnerships with other (like-minded) countries featuring complementary specialisations: the issue of economic security, as thoroughly discussed during the latest G7 meeting in Hiroshima and in the ongoing activities of the EU-U.S. Trade and Technology Council, is likely to involve such cooperation, rather than individual national strategies aimed at "going it alone".

Third, the strategic autonomy imperative may lead the EU to look into sectors, in which it lags behind but where it may have to reduce dependencies on other countries. Such sectors include *i.a.* semiconductors, as well as other forms of energy like hydrogen and domains such as cloud and edge computing, B2B digital platforms, AI and the IoT. For similar reasons, the raw material sectors have gained prominence within EU policymaking. All these are areas in which the EU has recently decided to massively invest resources and produce regulations to catch up with leading economies. In those domains, the launch of ad hoc large-scale projects and dedicated paths to create the necessary infrastructure and skills will be needed, alongside *ad hoc* subsidies or other support measures, mirroring the ones adopted by the United States with the CHIPS Act and the Inflation Reduction Act, among others.

Fourth, prioritisation of some policy domains and industry sectors may also be the result of a needs assessment, especially in the context of a goals-based strategy such as the pursuit of the Sustainable Development Goals. One good example is health, an area in which foresight and horizon-scanning exercises suggest the need to invest in new solutions to advance in the protection of the well-being of Europeans (and beyond).

This in-depth analysis of the possible future evolution of European industrial ecosystems would allow EU policymakers to identify possible trade-offs to be tackled through *ad hoc* policy mixes, including R&I policy, subsidies/state aids and regulatory policy. For example, a given transformation pathway may require access to critical minerals; or, alternatively, investment in R&I to develop solutions that would minimise the need for extraction of new resources, thus creating at once less strategic dependency and new jobs. Similarly, some pathways may require more international collaboration than others and may appear more vulnerable to external shocks than others. And importantly, different pathways may display different potentials for job creation and require different skills, which in turn would need to be mapped throughout the territory of the EU. Below, in Steps 3 and 4, we explore these two dimensions in more depth.

Step 3. Mainstream "good jobs" and needed skills in systemic Industry 5.0 transformation pathways

An essential step in the definition of the future systemic transformation pathways that are aligned with an Industry 5.0 paradigm is the mainstreaming of jobs quantity and quality, as well as related skills. This requires an analysis of the job-creating potential of different industry pathways, including existing jobs that will remain relevant in most or all future scenarios; jobs that could be created by securing adequate skills through *ad hoc* up- or re-skilling policies; jobs that may emerge in the future as a result of technology developments and/or megatrends.

Here too, a deep reflection will be needed to enhance the coherence of jobs and skills policies with industrial policy going forward. Currently, the integration of these streams is lacking in EU policy. Looking at the twin transition (and subject to the refined version of it that may emerge in Step 2 above), green and digital technology developments need to be combined and converted into knowledge, transferable skills and certifications. In turn, these need to be widely disseminated and rewarded to ensure the spread and depth of capability, and sufficient jobs to meet demand and retain talent in a context of urgent decarbonisation and shifting geo-political alliances. The European Pact for Skills and the New European Innovation Agenda represent a means of doing that if fully integrated into the higher education and vocational training agenda at pan-European, national and subnational scales; and if connected to the forward development of the European

Green Deal, Horizon Europe Missions, and European industrial strategy and policy under Industry 5.0 principles. The Pact for Skills should be used to ensure that Europe's R&I advantages are translated into market advantages through good jobs and relevant capabilities, including re-skilling and up-skilling across the board in manufacturing and operations (see e.g. McKinsey 2020), digital skills transfer between generations, investment in accessible education for SMEs and a focus on education for roles in the public sector to build the institutional cultural shifts, mindset shifts and paradigm shifts needed for public and private shared value creation and mutual transformation.[7] As ESIR observed in its paper on Industry 5.0, "The industrial transformation that Europe now needs to achieve sustainable living and the protection and regeneration of nature will require a comparable scale of radical change in ways of thinking and working, knowledge, core competencies, leadership and collaboration capabilities and above all, research and innovation practices."[8]

On skills, after two waves of scholarly literature devoted to an almost exclusive focus on STEM, and later coding skills, advances in Artificial intelligence and the need to secure a human-centric industrial transformation are prompting new thinking on the need for both complementary skills (both domain-specific and data-focused), cross-disciplinary analytical thinking, as well as emotional and soft skills. The new skill set for the future of the industry will therefore be at once composed of a mix of cross-cutting hard and soft skills, as well as IT skills that allow for optimal interaction with increasingly intelligent machines, which promised to commoditise mainstream existing knowledge, automating also non-routine tasks. The latter set of skills is also expected to need constant updates, and this in turn has consequences for education, lifelong training, up- and reskilling plans, as well as "training on the job" in industrial ecosystems. This highlights a further critical need and opportunity for Europe to build preparedness and shape the future of work in distinctive and geo-strategic ways. Systemic industrial transformation, as Industry 5.0 calls for, requires a necessary, complementary suite of skills, capabilities and mindsets that are transversal and transectoral – the next generation of so-called 'soft skills'.

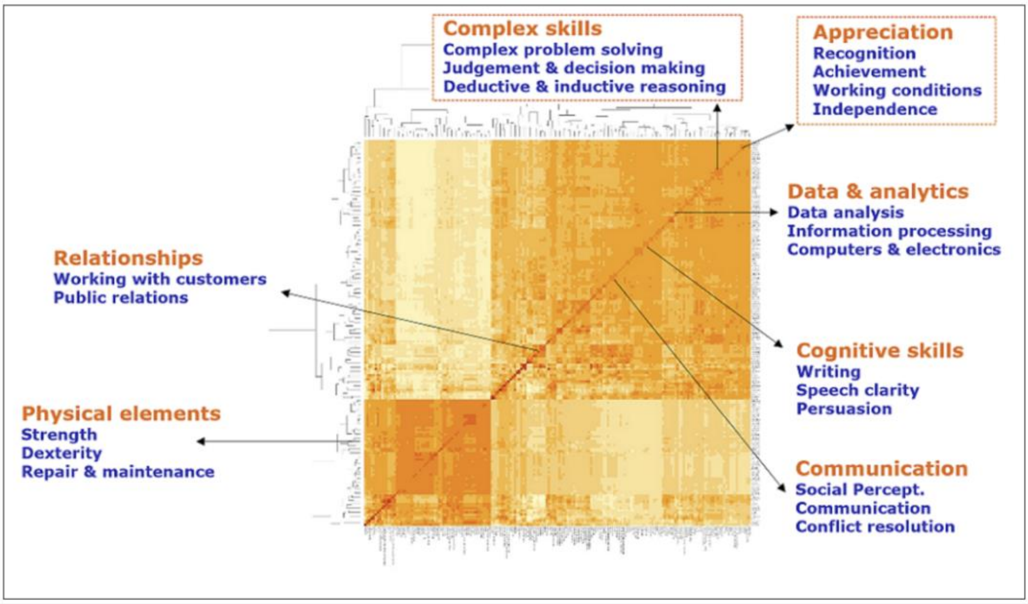
The need for such a skill set also emerges if one "lets the data speak", as we do in Box 2 below; and out of existing research initiatives, as in the case of "network intelligence" described in Box 3.

Box 2 – Let the data speak: the evolving landscape of skills

*Looking at what elements characterise jobs, and how they connect, is highly informative of the overall quality of jobs. Below, we "let the data speak", using O*NET data to observe the clustering of elements such as abilities, education, knowledge, skills, work activities, work styles, and work values. The clustering indicates the elements that are frequently associated with each other on the same occupational portfolio, for instance, complex problem-solving and working conditions. These elements and their connections represent the DNA of jobs.*

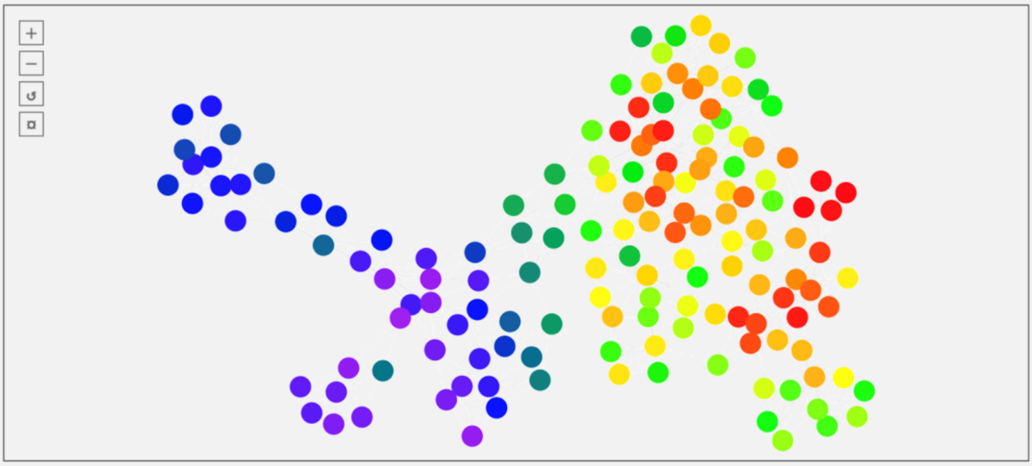
[7] See ESIR policy brief no.3 "Industry 5.0: A Transformative Vision for Europe", describing the need for 'government 5.0 to enable industry 5.0' including a number of shifts in skills and mindsets, pp. 14-22

8 Id., p. 20

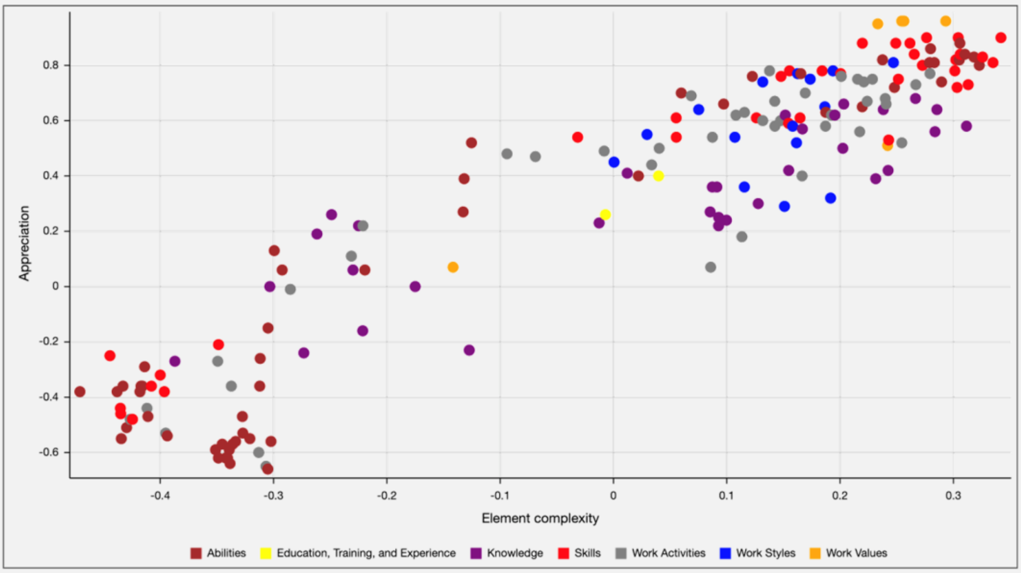


What is clear from this figure is the bimodal distribution of job elements, with the physical elements on one hand and the more mental/desk ones on the other hand. We observe the clear delineation of relationships, communication, cognitive skills, data analytics clusters, complex skills, and appreciation clusters (recognition, achievement, working conditions, independence). There is a strong structure in this data, and job boundaries shift as these elements become automated. These clusters indicate elements that workers can recombine to re-invent themselves. What is interesting is that the elements sort themselves into groups intuitively indicating some sort of job quality with complex skills and elements of job appreciation at the extreme top right. Our intention here is to call for more research on the structure of elements that characterize jobs to inform about quality, risks of automation, resilience, and skilling & re-skilling policy.

Another way to explore how elements connect is with graph visualisation. The interactive graph below shows the degree of relatedness (normalized co-occurrences) level between different elements. It means that if a worker shows a strong level in a given element, (s)he can easily move to another one. Skill-relatedness has been shown in the literature to be a powerful predictor of future skilling and upskilling and labour market resilience. At a more granular level, this information can be used to make useful personalized recommendations of what skills should be learned next to escape automation and poverty traps based on the very specific and unique skillset of workers. We can observe again the very sharp divide between the left side (manual) and right (cognitive) sides of the graph. The colours indicate the level of complexity of elements. More reddish colours indicate a high level of complexity, while bluer colours indicate less complexity. The complexity here uses a structural indicator from the field of economic complexity (see Balland et al. 2022). This structural indicator can be seen as an interesting proxy, enabling reflections on the quality of jobs in the context of rapid task automation. Complex elements are the ones that are highly in demand but are hard to train humans and machines for.



Complex skills are the future of AI-human work but what is interesting is that the cluster of complex skills forming with elements such as complex problem solving, judgment & decision making, and deductive & inductive reasoning is strongly associated with the appreciation cluster that combines recognition, achievement, working conditions or independence. Complex skills tend to correlate with excellent working conditions, i.a. because they provide workers with greater leverage vis à vis their employers.



Box 3 – Towards Network Intelligence: results from a research project

The post-Covid workplace requires new skills for innovation and industry transformation. One of the new frameworks is Network Intelligence deployed by The University of Manchester to build innovation and entrepreneurship capacity under the EIT HEI Initiative. Learnings from this programme - the Network Intelligence Academy - can inform policy making to better understand where in reality the top deep tech talent resides in Europe, what are they challenges and opportunities related to deep tech talent acceleration, to create "good jobs" locally, inspire brain *gain, and avoid brain drain. The Network Intelligence is a methodology built for enabling entrepreneurial talent to tap on the potential of the ecosystem. It is measured through the Network IQ Index, a coefficient built on a digital competency model enabling the strategic networking capacity for innovation. Once the adequate level of Network IQ skills is built across an ecosystem, the Network Intelligence Academy utilises a Purpose-Network Fit as a process model to optimise existing networks and build the networks needed for entrepreneurial growth. In September 2022, one of the EIT HEI's Pilot Call consortia, EntreUnity, presented its findings from an experimental development of Network Intelligence (nIQ) Academy. The Playbook presented a number of mini case studies showing how building capacity to utilise networks from innovation and innovation absorption by deep-tech start-ups from the Masood Entrepreneurship Centre at The University of Manchester. The learnings very organised following the framework developed by ESIR in the paper "The Future of European Universities". This framework was based on 6 areas for transforming talent supply at HEIs:*

1. *Dare to disrupt*
2. *Reform curricula and learning paradigms*
3. *Champion sustainability*
4. *Embrace the digital transition*
5. *Strengthen strategic collaboration networks*
6. *Focus on lifelong learning*

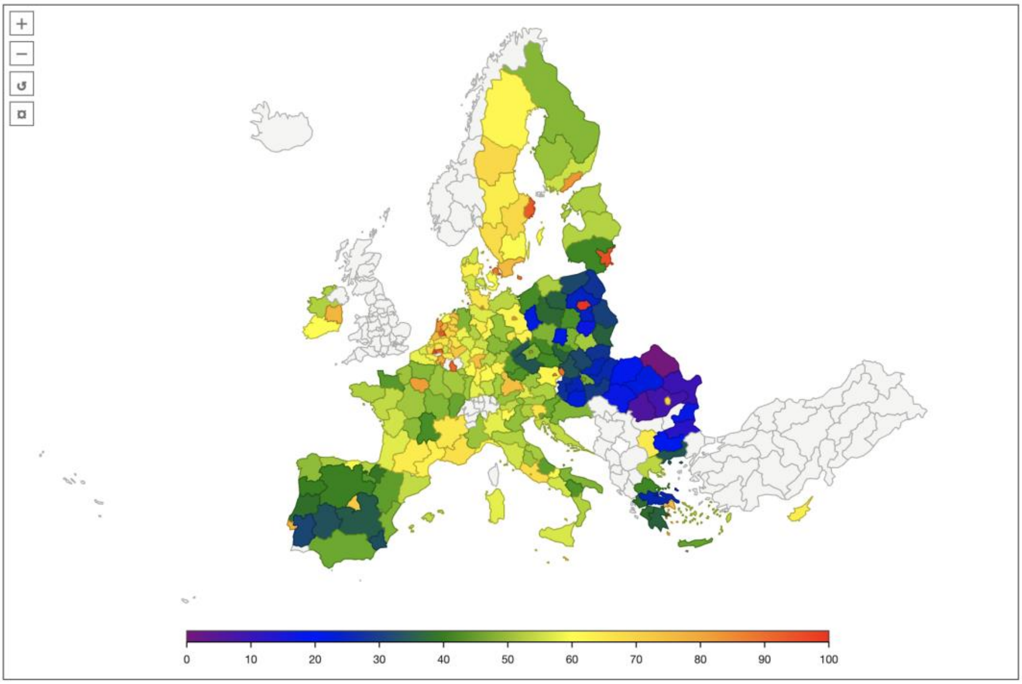
The case studies shed light on who are the best of the best innovators and entrepreneurial talent pointing to migrant and immigrant talent (similar to the paradigm of the Silicon Valley networks). The individual cases show how alumni of the nIQ Academy were able to find confidence shifting from the academic setting to business setting, find early adopters on 4 continents, fund raise, build partnerships with industry, and build communities advocating vital SDG-related agendas. At the same time, the Academy helped the innovation professionals at the University of Manchester increase their capacity to strengthen landmark government supported project that is Innovation District Manchester, a large-scale urban transformation geared towards boosting economic revival in the post-industrial Midland region and its historic centre. The case study shows that while universities have many networks and advanced entrepreneurship education offering, it is important that at the level of an ecosystem there is a sufficient level of capacity to utilised these networks for innovation, collaboration, business growth and sharing of resources. What is truly challenging is how to utilise these networks to build more effective ecosystems to increase innovation adoption. Tackling is major challenge was proven a efficient way to overcome a paradox of low growth and transformation dynamics in high-knowledge intensive regions with industrial past.

Step 4. Towards poly-centric governance: incorporate the regional dimension in EU industrial policy

One of the key elements of future industrial policy, as observed both by academics (e.g. Rodrik 2019) and in recent policy developments (e.g. the U.S. Regional Innovation Engines initiative) is the need to locate in regions in which the technology specialisation and the presence of appropriate domain knowledge and skills create fertile grounds for creating the good jobs of the future. Our next step is thus the coupling of systemic industrial transformation pathways with an adequate understanding of the specialisation of European regions.

Below, we show a map where we combined the previous O*NET structural data with the EU Labour Force Survey of the International Labor Organization at the regional (NUTS2) level. What is clear is that border effects are smaller than expected. In fact, it is hard to even distinguish national borders. This leads to the idea that good job policy should not only be a national level matter but also of a higher level of governance (EU). Another striking result is the clear West/East divide, with the jobs requiring complex elements concentrating in the West and less complex ones concentrating in the East. To a much lesser extent but also visible is a North/South divide. But maybe the most striking pattern of all is the extreme concentration of good jobs in the capital EU cities. This is true for all countries, but the pattern is even stronger in less developed countries. This marked geography of good jobs means that EU policymakers also need to take into account regional patterns of specialisation to fully accelerate the creation of good jobs.

Map of future regional intensity and distribution of new high-quality jobs in the EU (ESIR experts own calculations).



The good news is that we can leverage the specific skills of EU regional ecosystems by combining human and artificial intelligence. There is a remarkable amount of information on social, linguistic and economic structures. Amazon, Netflix, or Spotify use this information to predict what you will buy, watch or listen to next. ChatGPT and other LLMs use this information to predict what word comes next. Similar models are increasingly used to help prioritize public investment decisions (Balland et al., 2022). Combining the level of relatedness between technologies (as shown in the network presented in Figure 2) with a vector of existing specialisations of regions allows to map regional trajectories and therefore to optimize investment efforts at the EU level. Knowledge required to scale the development of carbon capture technologies might be located in a different region than knowledge required to scale photovoltaics. We need a truly place-based innovation policy that matches technology or industry investments with regional capabilities.

So we have the conceptual models and algorithmic principles. But do we have the data? For technology alone, patent data has been used extensively – and for good reasons. It is not perfect but it is a global, comprehensive, and highly standardized library of human technological knowledge with detailed geo-data. Scientific knowledge is also very well documented and geo-localized. But to fulfil the vision of this step 4 and connect science and innovation policy with good jobs and the future of work we need better pan-European data for skills, occupations and education. At the moment, researchers use employment data from the EU-LFS as presented here, national statistical offices, but also job boards and online platforms. There is a huge potential in connecting this job data to technology and industry data but we need more efforts in making this data more integrated at the EU level and more easily accessible to researchers, policymakers and citizens.

Step 5. A new *modus operandi*: mainstreaming jobs and skills in all EU, national and local policies and spending programmes

Once possible scenarios for the future evolution of EU industry and related services have been adequately mapped and analysed, and the regional dimension has been added, EU policymakers will have developed a more granular view of the objectives to be set in different industrial ecosystems, and in different portions of the EU territory. This should then be converted into a new *modus operandi* for all relevant policies at different levels of government. In particular:

- The EU's better regulation agenda should be reoriented to incorporate a few additional features. First, the problem definition phase should not be based on a mono-dimensional, single-scenario view of the future, but rather account for uncertainty and the poly-crisis, and thus present a more articulate view of how the problem might evolve absent a policy intervention. Second, alternative policy options should be assessed not only (and not necessarily) under a cost-benefit analysis lens, but rather through multi-criteria analysis (i.e, does the option at hand contribute to the "North Star", expressed in terms of "people, planet and prosperity" as illustrated in Section 1 above); trade-off analysis (do different options contribute in different ways to economic, social and environmental objectives, such that trade-offs can be identified and addressed?); and resilience analysis (which of the alternative options is more resilient to possible future changes and unforeseen events?). Third, the monitoring and evaluation of the selected option over time should incorporate stress-testing methodologies for resilience, as well as alignment with the foreseen systemic transformation pathways. In all these steps, the jobs and skills dimension would then be automatically incorporated in the analysis, and will count in the selection of the preferred option. The better regulation toolbox would thus need to be adjusted to reflect the need for EU policies to align with medium-term social, economic and environmental objectives (e.g. the SDGs), which incorporate full and decent employment targets (e.g., in SDG8)

- The priorities pursued by EU R&I policy, especially when it comes to innovation, should reflect the innovation needed to realise the vision built through Steps 1-3. This is particularly the case when it comes to missions and partnerships, which should incorporate an Industry 5.0 approach (where relevant) and be aimed at supporting the EU's innovation landscape with those solutions that can help the EU achieve its long-term goals. This will not be an entirely new feature in the future FP10, if one considers that the SDGs were already presented as the key long-term goal of the Horizon Europe framework programme.

- For what concerns jobs, it is essential that the EU and Member States consider (good) job creation as a conditionality when analysing and approving future policy and investment measures. This can be achieved in various ways, including *i.a.* by: (i) including the creation of good jobs in the criteria/conditionalities to be met in the allocation of resilience and recovery funds under Next Generation EU; increasing futures literacy capacity (UNESCO, OECD) across society and among policy-makers; promoting a model of corporate governance that goes beyond shareholder and stakeholder models, and incentivises the orientation of corporate conduct towards resilience and sustainability; engaging in proactive industrial policy to support the emergence of jobs in strategic sectors for the EU (also in view of the strategic autonomy imperative), as in the case of the Net Zero Industry Act; and matching existing technology specialisation with possible job opportunities and skills upgrading at the local level, in the context of regional innovation ecosystems. The underlying vision, as already explained, is that job creation and skills matching will increasingly become domain-specific, and geographically concentrated (as confirmed also by the U.S. National Science Foundation's new strategy on regional innovation engines).

- The Pact for Skills and related policies (e.g. on apprenticeships) should be guided by an understanding of which skills can be created/attracted, in which sectors, and in which parts of the EU. In a context of profound industrial, social and economic change, and the current and future context of poly-crisis, 'growth mindsets'[9], adaptive leadership approaches and interdisciplinary, boundary-spanning capabilities that are fit for embracing conditions of uncertainty, volatility and the discomfort of new things, and able to respond with agility and creativity, become critical success factors and indeed resiliency factors. They encompass skills and capabilities associated with systems and futures literacy, with exercising leadership in conditions of complexity through complex adaptive modes, with appreciation for interdependence and cross-pollination, working with guided emergence and participatory decision-making: soft skills that enable willing self-transformation, mutually transforming relationships and social cohesion in conditions of uncertainty and change. Leading edge capabilities in this aspect of human development are at least as important as the technical skills associated with new technology development for a sustainable and competitive future of work since these are the capabilities that influence and shape behavioural change, perception and adoption, determination of meaning and decision-making amongst communities, decision-makers and governments. They are also the skills, capabilities and experience sets needed to make, shape and lead businesses and societies through change through new economics, new business models and new policy, used deliberately to create the transformative market conditions that are features of Industry 5.0.

- Usefully, the European Green Deal and in particular the Horizon Europe Missions constitute real-time contexts for the accelerated development 'on the job' of these leadership-in-complexity and change management capabilities. Missions also provide a framework for the integration of such capabilities and mindsets with the technical skills needed for accelerated technology development through large-scale on-the-ground implementation. In this sense, Europe is creating the conditions for leading-edge transformational leadership, skills development and skills mobilization in cities, regions and member states through programmes like the Missions, and would do well to support such development explicitly, and capitalize on the talent attraction and competitive advantage this represents. Furthermore, the New European Bauhaus and the emergence of a focus on European creative industries as a distinctive feature of Europe's approach to societal and economic transformation, is another example of Europe shaping the future of work ahead of others in remarkably astute ways. A rapprochement of arts and science in the context of the twin transition enables the reintegration of skills and capabilities that are humane and versatile, brings together critical and creative thinking, facilitates human-centric digitalisation and cybernetics, and captures global public imagination around an aspirational vision of sustainable, aesthetically rewarding wellbeing and meaningful work. Europe's next Renaissance could indeed lead the world through deep decarbonisation to a regenerative, just and inclusive civilisation. [10]

- Seen from a backcasting perspective, aimed at reaching the North Star identified in Step 1, the choice of how to approach economic integration in the EU becomes way more complicated than ever. The need to achieve well-being under a "people, planet and prosperity" lens may require a mix of traditional, market-led integration policies for a level-playing field in the Single Market; and more orchestrated, new-generation industrial policy measures aimed at subsidising and supporting regional, cross-ecosystem large-scale projects aimed at achieving decarbonisation and creating good jobs (e.g. the HYBRIT project in Sweden). As authors such as Pisani-Ferry (2023) and Tagliapietra and Zettelmeyer (2023) have recently highlighted, Europe is today forced to dig deeper into the emerging trade-offs between decarbonisation,

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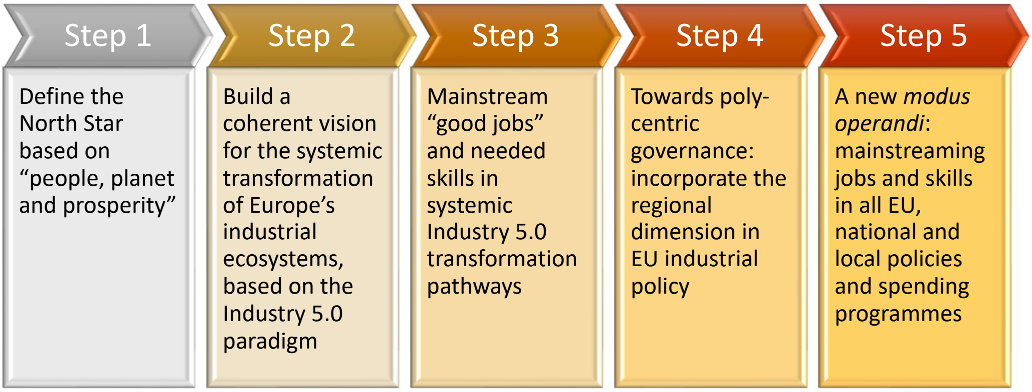
9 See Carol Dweck, *Mindset - Updated Edition Changing The Way You think To Fulfil Your Potential*, 2017

10 See Helga Nowotny, *Insatiable Curiosity: Innovation in a Fragile Future*, 2008. See also the ICE Project 'A Next Renaissance': https://www.nextrenaissance.eu/

job creation, competitiveness, and economic security. In this respect, the Single Market should be approached as an intermediate goal, not as the ultimate frontier that the EU aims at reaching in the medium- to long term.

Figure 4 below shows the main steps described above.



Conclusions

In this paper the Expert Group on the Economic and Societal Impact of Research and Innovation (ESIR) looks at the intersection between industrial transformation and the need to ensure a human-centric, resilient, and sustainable future, in terms of job creation, future trends and the evolution of employment and particularly the question of wellbeing especially at the workplace.

In its latest publication, the group underlines that Europe is uniquely placed to leverage the growing demand for "good jobs", and this advantage may become a key pillar of Europe's industrial policy and geo-strategic positioning in the years to come.

The ESIR group has on several occasions supported the aim to promote a systemic industrial transformation that goes beyond the deepening of digital technology in industry, to embrace a human-centric, resilient and sustainable paradigm.

The "Industry 5.0" approach, still far from universally acknowledged, is key for the future of the European economy, and a much-needed step to ensure that industry becomes a protagonist, rather than a passive factor of transformation. In this policy brief, ESIR looks specifically at the intersection between industrial transformation and the future of work.

The paper unpacks the notion of workers' well-being and quality of life, as foundational elements of Europe's vision for the society of the future. The paper calls for a new vision of the future of work and industry 5.0 in the broader context of the Net Zero and Fit for 55 global endeavours.

Annex 1 – Europe's relative specialisation in green transition technologies

We analyse the position different countries have as innovation producers of the twin transition. Our patent data analysis - as displayed in the figure below - indicates that European countries (understood as the group composed by EU27, the UK and EFTA countries) are the leaders of the green transition. From 2016 to 2021, Europe has produced a whopping 30% of all green inventions worldwide. Japan comes second, with 21%, followed by the US (19%) and China (13%). The European dominance is especially strong for domains such as green transports (41%), biofuels (37%) and wind energy (58%). The production of solar energy technology or batteries is more evenly distributed among the largest and most innovative countries. An interactive visualization version of the leaders of the green transition can be explored at this address[11].

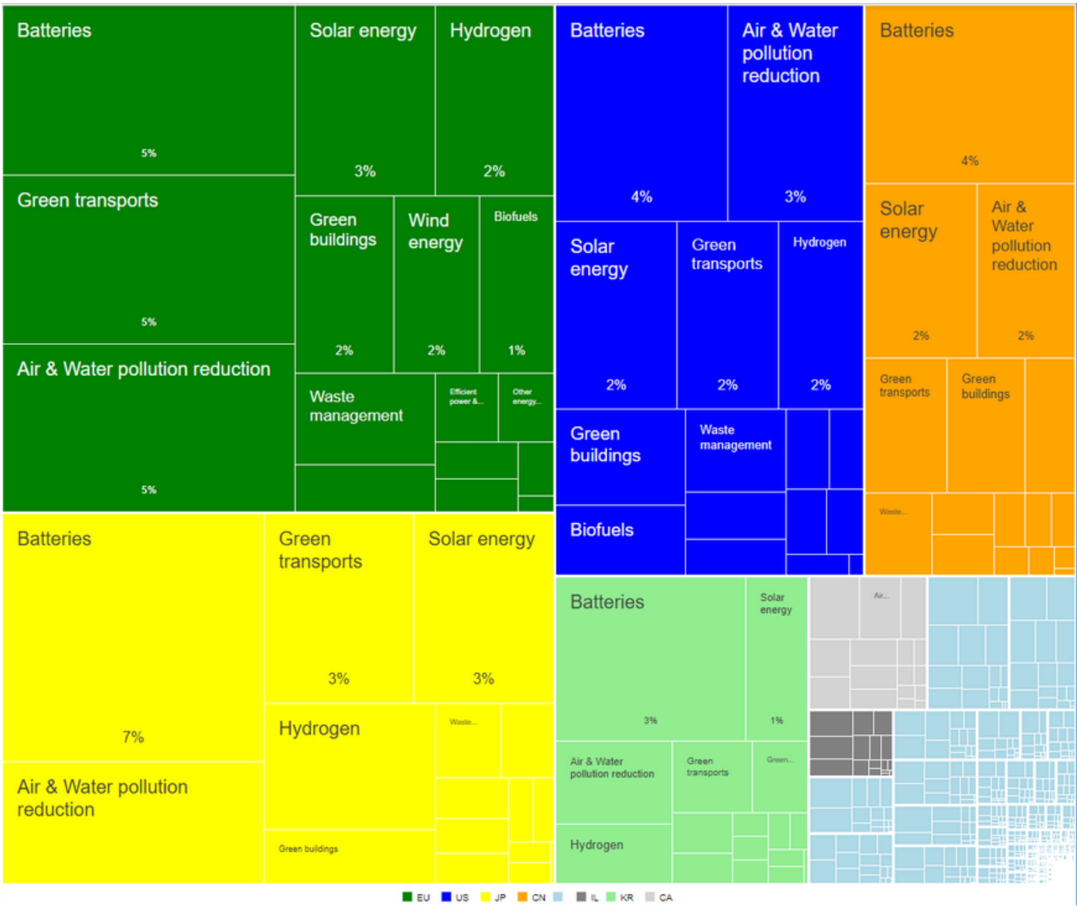


Figure - The leaders of the green transition

Europe also shows strong innovative capabilities in the digital transition, but is clearly not as dominant as in the green transition. As the figure below indicates, the clear leader in the digital

[11] https://www.paballand.com/asg/esir/fow/green-transition.html

space is the United States, with 38% of digital patents coming from inventors located in the US. China comes second with 22%, closely followed by Europe (19%) and then Japan (10%). Artificial intelligence is an area where EU investments are particularly needed, with only 14% of the patents coming from Europe, as opposed to 38% and 20% for the US and China. Europe, however, leads in additive manufacturing (37%), autonomous robots (26%) and is on par with the US and China when it comes to autonomous vehicles. An interactive visualization version of the leaders of the digital transition can be explored at this address[12].

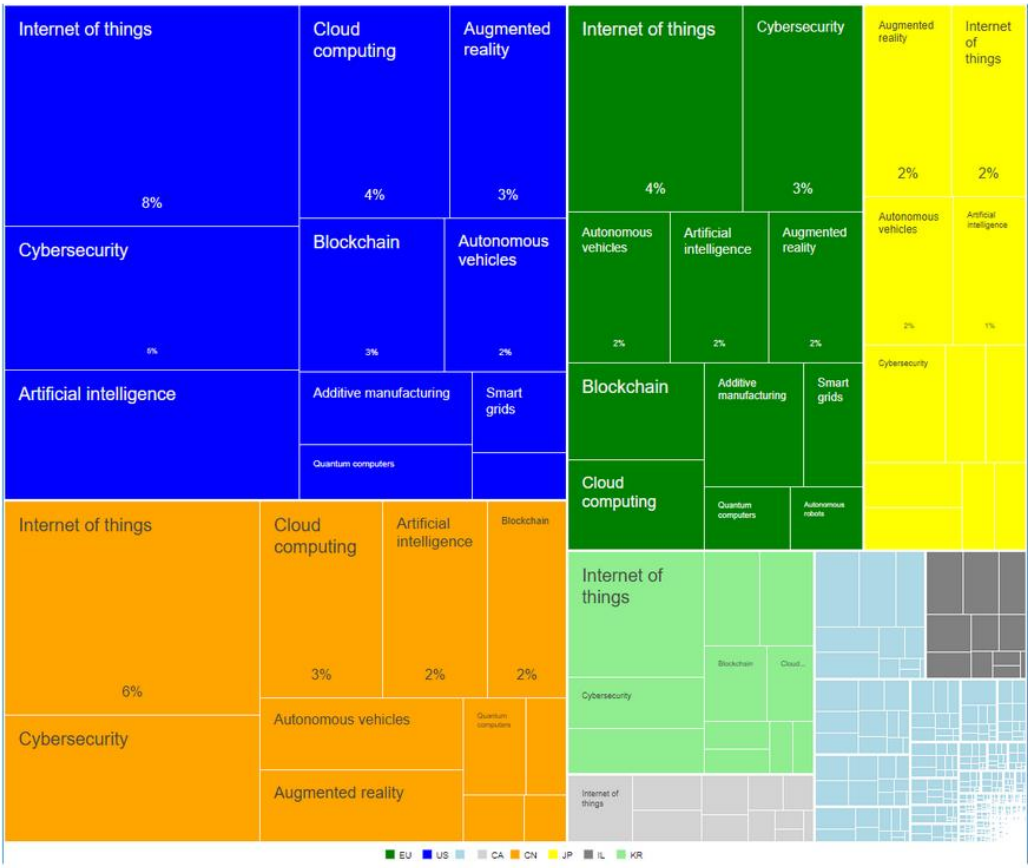
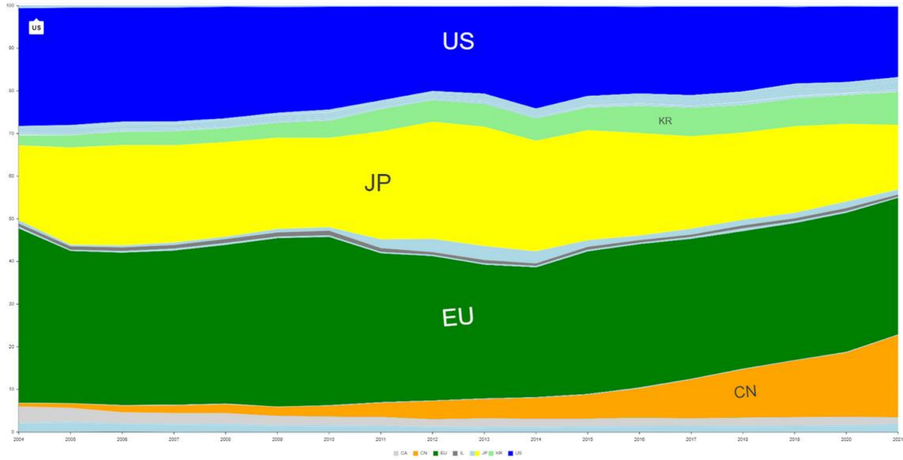


Figure. The leaders of the digital transition

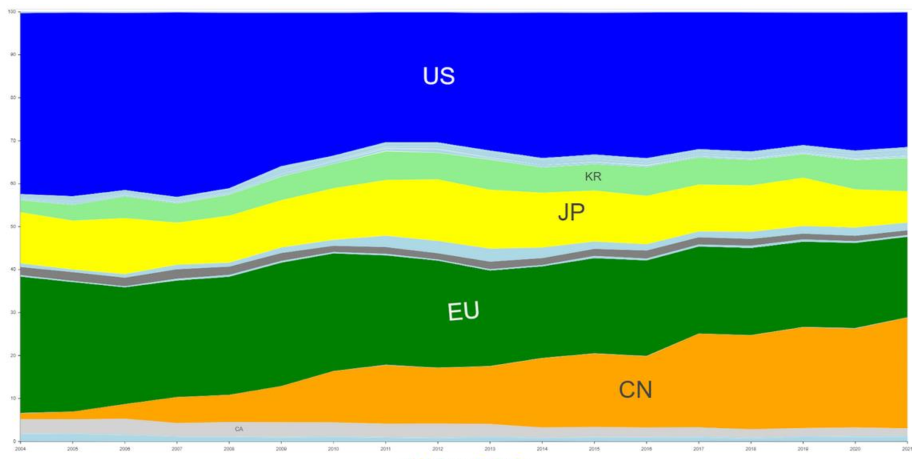
In dynamics, Europe has maintained a fairly stable position in the green transition since 2004 (figure 4). We can observe a slow down during the 2008 financial crisis, but innovation has been relatively stable since 2014. This is remarkable, in the sense that this stability happened despite the meteoric rise of China. In less than 20 years, China increased its production of green patents by almost 20x. The main loser in terms of proportion is the United States, from almost 30% to about 20% now. Japan is also on a declining trend since the 2008 financial crisis. An interactive visualization version of the dynamics of the leaders of the green transition can be explored at this address[13].

[12] https://www.paballand.com/asg/esir/fow/digital-transition.html

[13] https://www.paballand.com/asg/esir/fow/green-transition-velocity.html



The dynamic analysis of the digital transition leadership gives a very different picture. In this case, the early 2000s' was divided between the United States and Europe, with a clear advantage for the US. Since then, the relative performance of Europe has shrunk from 30 to less than 20%. The leaders of the digital transition are clearly the US and China. If the trend continues, China will be the #1 digital innovation producer in a few years. South Korea tends to increase its relative position, while Israel is still largely punching above its weight. Japan is showing signs of slowing down. An interactive visualization version of the dynamics of the leaders of the digital transition can be explored at this address[14].



[14] https://www.paballand.com/asg/esir/fow/digital-transition-velocity.html

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The ESIR group has on several occasions supported the aim to promote a systemic industrial transformation that goes beyond the deepening of digital technology in industry, in order to embrace a human-centric, resilient sustainable paradigm. The "Industry 5.0" approach, still far from universally acknowledged, is key for the future of the European economy, and a much-needed step to ensure that industry becomes a protagonist, rather than a passive factor of transformation. In this policy brief, ESIR looks specifically at the intersection between industrial transformation and the future of work.

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