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Technological and innovation challenges for industry: Science for policy insights

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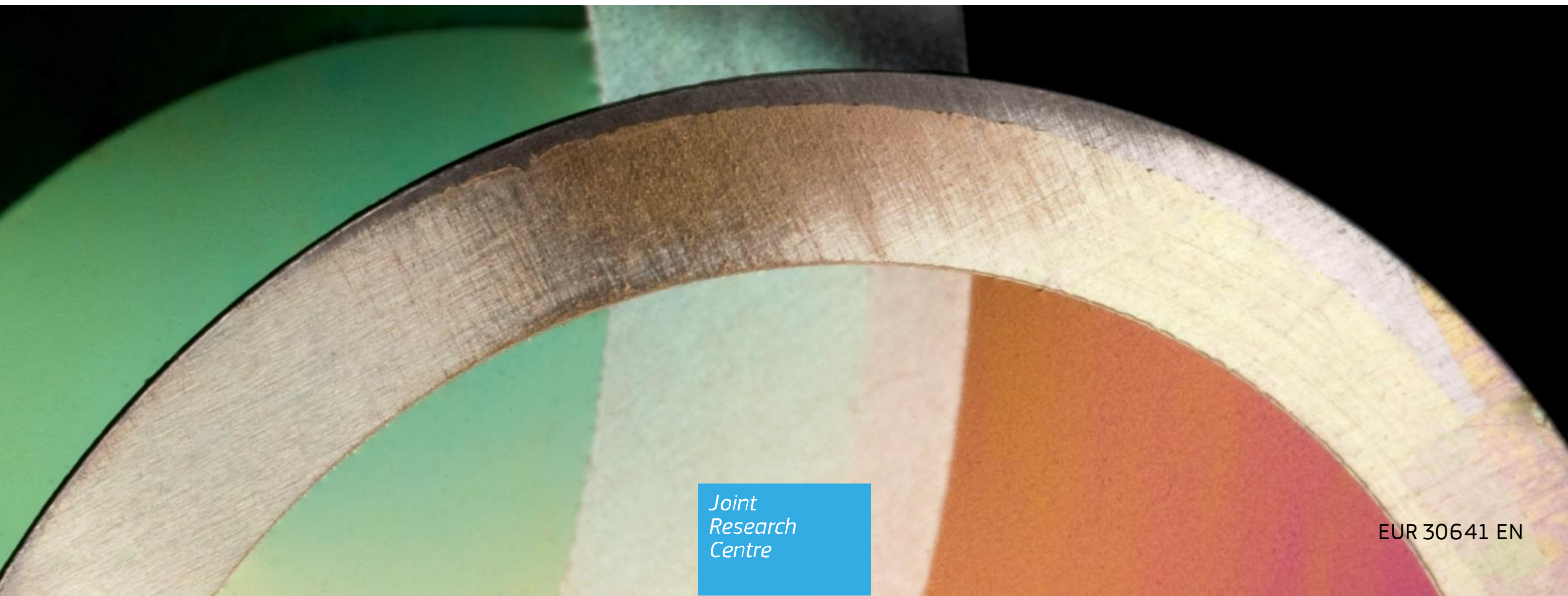

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Abstract

This report contains the results of a selection of European Commission’s JRC activities which aim to support EU policies to tackle the technological and innovation challenges of the EU industry in the next decade.

It addresses some of these challenges by implementing scientific analyses resulting in novel contributions within the following themes: Technology diffusion and industrial dynamics; innovation and company value chains; Financing innovation; Industrial innovation for transitions and transformation; Employment and skills for industrial transformations; Integration of global to local industrial innovation perspectives; and new data, standards and methods.

The outcomes obtained provide evidence and insights relevant to EU policy initiatives dealing with innovation and industry and aiming to achieve the 2019-2024 priorities of the European Commission's "Green Deal" and "A stronger Europe in the world", and in general the EU industrial competitiveness and sustainability.

Acknowledgements

The present report is based on a collection of thematic outputs from the 2019-2020 workprogramme of the European Commission's Joint Research Centre (JRC). These outcomes were in part implemented in the framework of the workpackage "technological and innovation challenges for industry 2030 strategy" (TIC 2030 Strategy). Other analytical results presented in this report come from further work packages and related studies from the JRC work programme of the same time.

This work has greatly benefitted from the collaboration of colleagues and peers within and beyond the European Commission. In particular, we acknowledge managers and peers across JRC services dealing with industrial and technology innovation who have provided the necessary support to the work that fed the present report. The authors would also like to thank colleagues from other European Commission services for their comments and suggestions and, the anonymous reviewers for the remarks received in the framework of the JRC Editorial Review Board quality check process. We acknowledge the helpful support offered by our JRC colleagues Tanja Acuna and Úna Cullinan during the publication process as well as colleagues from the Publications Office of the European Union who have proofread with accuracy and speed the English language of this volume.

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Projecting opportunities for industrial transitions: .... *Dimitris Pontikakis, Anabela Marques-Santos and Mark Boden (JRC B.3)*

Industrial innovation for transformation: .... *Pietro Moncada-Paternò-Castello, Alexander Tübke and Emanuele Pugliese (JRC B.3)*

Summary and conclusions: .... *all the above*

Executive summary

This report provides an outline of the analytical results obtained by the Joint Research Centre (JRC) of the European Commission. It focuses on selected recent activities in the area of technological and innovation challenges for the EU industry. The objective is to obtain impactful insights that are of interest to policy-makers, to provide them with a cross-cutting overview of different analytical aspects of the industrial innovation field, developed thanks to the JRC's frontier scientific knowledge and analytical capacity to support EU policy-making in this area.

Policy context

The EU is facing multiple economic, societal and environmental challenges. Some key objectives of the EU include improving its economic prosperity and growth in productivity, increasing its competitiveness on global markets and creating more and better jobs in a sustainable way. Recently, the European Commission has stressed the role of industrial innovation in achieving competitive sustainability in the EU in the context of the recovery plan[1], and supporting the green and digital (twin) transition. EU industrial innovation will play an important role tin bouncing back from the coronavirus disease 2019 (COVID-19) crisis by providing innovative solutions and creating new business and employment opportunities.

Main findings

Industrial technology and industrial dynamics depends very much on specific characteristics of the market and of the sectoral structure, and on regulatory models. The analysis of **industrial innovation and company value chains** reveals that fast-developing local strengths and the related science and technology fields are shaping companies' geographical distribution of research and innovation (R & I) activities especially in Asia. In the EU the strongest value chains are in more traditional sectors. Moreover, the analysis indicates that the reshoring of production through the relocation of resources to more efficient EU production units would require persistent innovation activities, e.g. in the form of scientific research and development (R & D), software development or information technology (IT) services, as a recurrent key factor for such gains.

The analyses of **financing and taxations,** crucial issues for industrial innovation - especially for some types of firms, indicate considerable differences exists between the volumes and patterns of funding for innovative firms, depending on whether it is provided by public or private entities. In addition, empirical evidence shows that countries and regions in Europe need all three forms of finance – seed finance, start-up capital and growth capital – for the emergence of companies with growth potential. Seed and 'early' finance are the categories of finance most adversely affected by the COVID-19 crisis. The analysis of R & I and taxation suggests, for example, that patent boxes (special very low corporate tax regimes) reduce the impact of high effective tax rates, which lower the number of patents registered in a given country. Furthermore, the size of the digital sector in a country tends to be negatively related to the changes in corporate income tax revenues. This is more pronounced the larger the share of non-routine profits.

The work on **innovation for industrial transformation** challenges indicates that recent innovations and integrated production structures need updated management practices, and that territorial and economic disparities and firms' heterogeneous performance depend on the differences in innovation diffusion and adoption rates. The research into **digital transformation and artificial intelligence** uncovers analytical insights into the role of data and platforms, into the development of artificial intelligence and advanced technologies, and into innovative public services. For example, it reveals that the adoption of programming interfaces in organisations acts as a catalyst of digital transformation processes, fosters innovative processes with relative low investment efforts, produces efficiency gains, and enables digital interactions with internal and external stakeholders. Furthermore, these activities provided the first ever evidence of the role and strategies that some digital platforms employ to leverage their dominant positions vis-à-vis their different groups of users.

Key aspects of **employment and skills** for industrial transformations emerged from several work streams. They suggest that the distribution of the benefits of technological changes, the increased access to the benefits and utilization of changes, and the support for individual and institutional adjustment to changes

[1] In the framework of the "Recovery and Resilience Facility", a key instrument at the heart of NextGenerationEU to help the EU emerge stronger and more resilient from the current crisis.

need to be carefully analysed and managed to choose the right policy mix. Such analyses also found that employees are more inclined to move among R&D intensive multinational corporations and their subsidiaries than between these firms and other firms in the economy. This holds especially for highly skilled employees. Moreover, mixed consequences for the labour force and structural inequalities arise from advanced digitalisation – some forms of innovation seem to favour employment and wage growth, whereas others lead to the loss of jobs – while sustainable technologies may have a major positive impact on employment and industrial composition.

The **integration of global with local industrial innovation perspectives** is one of the key challenges. The findings reveal that EU-level, national and local policies are able to create favourable conditions for attracting foreign direct investments in R&D. However, such investments concentrate in hub locations, which raises concerns related to increasing regional inequality, but a proliferation and interconnection of such hub regions or urban agglomerations also helps to link distant locations and fragmented innovation systems.

In a rapidly evolving socio-economic environment and a new EU policy agenda, the analysis of industrial innovation needs to rely on **new data and new methods**. This volume reports on new methodologies developed and implemented by the JRC, such as for the review of **industrial transitions** to provide evidence in support of system-level innovation in lagging regions of the EU, or a **complexity** analysis applied to methods of industrial innovation and competitiveness, allowing disaggregated examinations of specific sectors at the territorial level.

Key conclusions

In the context of the new EU industrial strategy[2], not only does innovation offer the potential to achieve the sustainable and human-centred aspects, but the uptake of innovation is also key to wider benefits for the EU economy and society at large.

EU policies should aim to pull in more private R & I investment in the development of key strategic industrial technologies, such as those related to digital transformation, to energy, environmental and resource-efficient technologies, and to enabling technologies (such as new biomaterials, metals, polymers and advanced manufacturing), by providing a common vision for R&I action.

The EU's structural change towards more knowledge-intensive sectors is slower than those of its main competing economies. That is the basis of the EU's R & I and competitiveness gaps. The role of new, innovative firms – still insufficient in the EU – is crucial for such structural dynamics, as they are able to create new knowledge-intensive sectors or enter them early, and compete and grow in them. Therefore, EU policies should address barriers that these firms encounter to entering R & I-intensive sectors and growing.

In addition, the improvement of the EU's capacity to transfer research results into economic successes is key because this rises productivity, creates new employment opportunities and improves the sustainable wellbeing of citizens. Moreover, new evidence provides a robust indication that new industrial innovation policies should be more and more tailored to differences in markets', sectors' and firms' typologies. Addressing crucial economic players' and territories' specificities will avoid disparities and provide suitable sustainable options.

The increasingly cross-disciplinary nature of the economics of industrial innovation calls for new statistical concepts, new data, complex analytical methods, and radically new policy designs that are able to consider the multi-dimensional (geographical, institutional, sectoral) aspects of the development of industrial innovation for transformation in Europe. It is worth mentioning that the new conceptual framing of transformative innovation can be usefully applied to the analysis of European innovation policies, especially with regards to transitions that require not just innovations at the level of organisations, but also architectural or system-level (macro) innovations.

The abovementioned cross-disciplinary nature of the economics of industrial innovation requires a more unified single market and further policy integration and coordination between the European Commission and Member States and stakeholders. The advantage of alignment and creating such key partnerships, under present and future programmes, is that it will create a new ecosystem, conducive to the intended transitions and transformation of the industry, which will capitalise on the EU's regional diversity and competitive advantages.

[2] European Commission (2020), Commission communication – A new industrial strategy for Europe (COM(2020) 102 final),

The present EU policy agenda and the related instruments represent a great opportunity to attain the intended objectives by exploiting the full potential of technological innovation developments and the key role of EU industry in those developments.

Related and future Joint Research Centre work

The work presented in this report is part of the JRC's 2019–2020 work programme (TIC 2030 strategy). It relates to several work streams of the JRC and of other services of the European Commission. The continuation of these activities in 2021–2022 is assured by the 'Industrial innovation for the Green Deal, strategy and coordination' project; it aims to tackle the new science for policy challenges to support the green agenda, and the associated industrial and R & I policies.

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1. Introduction

1.1 Motivation, aim and objectives

The European Commission political guidelines for 2019–2024 and its recent proposal for 'A new industrial strategy for Europe' (European Commission, 2020a) underline the importance of industrial innovation to contributing to its main objectives. At the heart of such policy references is the ability of Europe's industry to lead the twin transitions – green and digital – and drive our competitiveness, becoming the accelerator and enabler of change and innovation. This will require coordinated and targeted mobilisation and deployment of Europe's scientific excellence, research, innovation, investment, and societal assets, institutions and capacities. It will also require an advance in scientific knowledge to be able to support policymaking to achieve such ambitious strategic policy objectives.

The aim of this report is to provide a snapshot of relevant results obtained by activities implemented by the Joint Research Centre (JRC) of the European Commission. The work was implemented in the framework of the technological and innovation challenges for industry 2030 (TIC 2030) strategy)[3], a work package of the JRC work programme 2019–2020.

The content of this report focuses on the technological and innovation challenges for European industry, indicates the limitations and suggests the way forward. It does not encompasses the full range of JRC activities in this field. The objective is to offer a pertinent sample of the frontier scientific knowledge and analytical capacity developed by the JRC in this area to support EU policymaking.

The science for policy work displayed in this report, which has been carried out by different teams in the JRC, often across JRC units and directorates, is mostly based on quantitative analyses, and relies on collaborations and validations offered by colleagues from other directorate-general and by external experts, and through ad hoc workshops and conferences.

The two following sections provide background on the state of the art of EU policy in the field of industrial innovation, and the scientific knowledge still required for sound support to the new industrial innovation policy. The last section of this chapter introduces the structure of the entire document.

1.2 A new policy framework

The European Green Deal communication (European Commission, 2019) set out the **path for the initial priority actions** to be undertaken during the next few years. These are moving targets to be updated as **different policies evolve**, and constitute an integral part of the Commission's strategy to implement the **United Nations 2030 agenda** and the **sustainable development goals**.

The Green Deal initiatives included in the Communication are reflected in the **Commission Work Programme for 2020**.[4] They correlate with other generational challenges of our society. **Digital transformation** and tools will be essential enablers of the European Green Deal-driven changes. At the same time, the digital sector should also put sustainability at its heart. '**'Green deal diplomacy**'' is needed to bring our global partners on a sustainable path.

The implementation of Green Deal objectives should also **enhance the EU's economic competitiveness**, thus ensuring stronger, more cohesive and more resilient European societies. For all of this to happen, **consumers will need to play an active role** in the ecological transition through, among others, behavioural changes.

[3] The main aim of the TIC 2030 strategy is to offer better JRC support to EU policies to tackle the technological and innovation challenges facing the EU industry. The objectives of the TIC 2030 strategy are first to improve internal coordination and priority setting, and then to offer a consolidated view of JRC (Directorate B) knowledge and capabilities vis-à-vis various directorates-general (DGs). This translates into sharing information and planning future activities between JRC services to have a greater impact on the EU industrial innovation policy.

[4] European Commission (2020) Adjusted Commission Work Programme 2020. Brussels, COM(2020) 440 final. Brussels, 27.5.2020.

Industrial sectors and value chains will have to go through a very rapid **green and digital transformation** in the coming years, towards a sustainable model of inclusive growth, embracing an improved environmental footprint along all steps of the value chains.

With the new industrial strategy, investments in **strategic value chains** – e.g. for batteries and bio-based products – and **new forms of collaboration with industry** will be essential for ensuring Europe's **strategic autonomy** and **technological leadership**.

Championing the "**twin ecological and digital transition**" (European Commission, 2020c)[5] will also need technologies to be continuously improved and **potentially disruptive technology options** will have to be driven from niche to norm. **Place-based innovation and ecosystems** are necessary in order to provide European **start-ups and fast-growing companies** with a **competitive edge in the global markets**.

Investment in research and innovation (R & I) is **key to achieve the Green Deal and industrial competitiveness** within the above policy objectives. It is accompanied by the **sustainable finance package** (6). Related to this, the action plan for financing sustainable growth (European Commission, 2018) and the EU taxonomy on sustainable finance (7) will require listed companies to disclose financial metrics regarding climate change mitigation and adaption, reduction of energy and other material input, recycling, and preservation of our planet and ecosystems. The upcoming **renewed European Research Area** (ERA) will continue to incentivise research and development (R & D) investment from the private sector, bringing R & I and industrial policies closer together within the Commission's priorities. The new element of **directionality for R & I policies** will strive to understand, monitor and enhance impact in line with the above Green Deal priorities. In conjunction with ERA and R & I policy directionality, more sophisticated tools to enable synergies between policy instruments of **Horizon Europe** and the industrial policy agenda are necessary.

The **importance of industrial innovation** to contribute to these broad transitions and sustainability objectives is reflected in recent key policy documents and in particular in the Commission communication '**A new industrial strategy for Europe**' (European Commission, 2020a)[8].

The **drivers behind the new strategy for the transformation of European industry** are the following: (a) ambition for globally competitive and world-leading industry (whereby Europe must leverage the impact of its single market to set global standards); (b) climate neutrality (with the Green Deal as a growth strategy); and (c) digitalisation (allowing industry and small and medium-sized enterprises (SMEs) to be more proactive, providing workers with new skills and supporting the decarbonisation of our economy).

Such strategy setting aims to attain efficiency and growth achieved through digitalisation and the process of 'greening' the economy and society. In this setting, the industrial transformation and innovation are pivotal for the twin transitions.

1.3 Science required to support new industrial innovation policy

The new EU policy needs to rely on a sound scientific basis. However, there are still important evidence-for-policy gaps, as new evidence required is not always available. These gaps could in part undermine the efficient achievement of the previously introduced policy goals. Important areas where evidence is required for the new industrial innovation policy are suggested below[9].

Industrial technology diffusion, structural changes and sustainability. The EU depends on access to critical technologies from other countries in the world and needs to improve its assessment capabilities in order to identify industrial R&D investments gaps, drivers, and barriers. Moreover, the social, economic, political, and environmental impacts of the EU's multitechnological dependence should be investigated further. That would be important evidence for enabling the appropriate selection of technologies relevant to achieving sustainable competitiveness and socioeconomic prosperity. For this purpose, measuring the levels of

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[5] COM(2020) 37 final

[6] This will triggering EUR 1 trillion in investment over the next decade (last update on 5 August 2020); see also European Commission (2018).

[7] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020. on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088

[8] European Commission (2020). A New Industrial Strategy for Europe. COM(2020) 102 final Brussels, 10.3.2020.

[9] This section is based on Amoroso et al. (2019) and Moncada-Paternò-Castello et al. (2019).

intangibles or complementary assets becomes even more important. Furthermore, digitalisation, new technologies and their diffusion, new business models, and major industrial transitions in energy and transport systems, call for more analytical information as a basis for comprehensive policies. The transformation of EU industry requires profit, investment, and employment incentives to be aligned with pressing environmental and social needs. The digitalisation of consumption and production, artificial intelligence (AI), and new platform technologies are driving change, and at the same time new business models are enabling major transitions in transfer methods for new products and services.

Industrial innovation and companies' value chains. The contribution of digital technologies and digital economies to growth in global and EU value added and productivity needs to be monitored accurately. Reaching the critical masses of investment (human capital, financial capital, infrastructure, etc.) requires the identification of appropriate industrial innovation partnerships in priority technological areas and industrial activities. The impact of these partnerships will also depend on the innovation diffusion patterns, the enabling public facilities and bodies, and the spatial and economic impacts of strongly networked firms. These dimensions should be analysed further. A better understanding of the factors (public policies and tax systems, among others) that prevent SMEs from accessing the benefits of digitalisation would help policymakers to take appropriate actions to facilitate market entry and innovation by SMEs.

Financing innovation. The new financial crisis due to the pandemic disease and the related difficulties in access to credit - on which innovation activities crucially rely - has renewed the attention of stakeholders. In spite of past developments in theoretical analysis and in the data and methodologies for empirical investigation, some issues have remained unexplored to date. Financing constraints affect investment and economic performance differently depending on the specific geographical and socio-institutional context, the structural characteristics of the relevant firms, and the economic sectors in which they operate (Dosi, 1990)[10]. For this reason, analyses using European innovative firms had to take into account a somewhat different industrial structure, marked by the dominance of SMEs in most medium-high tech sectors, accompanied by a number of idiosyncratic elements in the functioning of capital markets and financial intermediaries: the quantitative and qualitative deficits of the European venture capital (VC) industry (Hall *et al*., 2016)[11]. This has led to a better understanding of the relationship between private investments and public grants to SMEs within the EU.

Industrial innovation for transitions and transformation, and the required employment and skills. Policymakers should rely on sound evidence of how to improve the incorporation of socioeconomic aspects, that is, those relating to quality of life and well-being, in industrial innovation and transformation strategies. Furthermore, so that industrial innovation targeting the three sustainability dimensions (economic, social and environmental) can be enabled, the capabilities and skills required by different types of actors need to be understood better and probably need extending. The ongoing technological and socioeconomic transformation may create new jobs. Indeed, advanced industrial innovation triggers a 'creative destruction' process revealing the redundancy of old investments and professions (Moncada-Paternò-Castello *et. al.*, 2019)[12].

Integration of global with local industrial innovation perspectives. Industrial innovation has a strong territorial dimension. Leading firms organise their knowledge–intensive activities globally. Our collective understanding of them is patchy and incomplete, with progress hindered by the limited availability of data on R & D, and on other intangible investments and knowledge-intensive business activities, especially at the regional and sub-regional levels. Decades of innovation studies emphasise the processes of accumulating capabilities of innovation. Europe is making massive investments in knowledge and innovation which foster broad capability accumulation and convergence. Of principal importance is the extent to which capability accumulation takes place within firms. Evidence from micro-data is increasingly important in understanding

[10] Dosi, G. 1990. Finance, innovation and industrial change. *Journal of Economic Behaviour and Organization.* 13 (3): 299-319.

[11] Hall, B. H., Moncada-Paternò-Castello, P., Montresor, S., & Vezzani, A. (2016). Financing constraints, R&D investments and innovative performances: new empirical evidence at the firm level for Europe. *Economics of Innovation and New Technology*. Volume 25, 2016 - Issue 3

[12] Moncada-Paternò-Castello, P., Amoroso, S., Pontikakis, D., Pugliese, E. and Tübke, A. (2019), Industrial innovation for transformation – 7th European Conference on Corporate R & D and Innovation CONCORDi 2019 – Background note, JRC Technical Report, EUR 29842 EN, Seville, European Commission, doi:10.2760/963644

industrial innovation dynamics, particularly the secular trends of divergence in intangible investment and productivity between leading and lagging firms (see for instance Bauer *et al.*, 2020)[13].

Data and measurements for the new industrial innovation policy. To be able to measure the issues related to industrial innovation and the main challenges in the socioeconomic transformation, the EU should equip itself with an appropriate statistical and analytical framework of new and open access data and standard analytical methodologies. There is still considerable work to be implemented to gather standardised data at the industry level about sustainability indicators, in order to achieve, for example, the sustainable development goals. Furthermore, innovation systems are complex, characterised by different layers of interaction between agents in different domains: science, technology, government, production. The interactions between different firms, countries, and regions, and their capabilities, play a central role in understanding the system. This creates a scientific challenge if traditional approaches are commonly used in economic analysis.

The new EU policy era will need much more than just monitoring tools for industrial investments in R&I. It will also need thorough and sound information to help policymakers remove obstacles to investment, foster diffusion and skills, provide visibility and technical assistance to investment projects, and make smarter use of new and existing financial resources. Some of the key JRC science for policy activities, which have dealt with these issues, are introduced briefly in this report as specified in the following section.

1.4. Structure of the report

Eleven main chapters follow this. They contain an outline of the main research and analytical activities conducted in 2019–2020 by the JRC. Each chapter, except the conclusion, contains the following information: **(a) participants and collaborations** (Who has been participating collaborating from the JRC team/unit across units and directorates?); **(b) activity** – current understanding (What is known about this problem?), research question(s) (What is/was the activity's goal?), methodology / data used (How was the work carried out?), findings (What are the main outcomes?), and contribution to science and policy, and practical implications (What does the work add to current understanding? Who will gain from the findings, why and how?); **(c) limitations, follow-up and further collaborations**.

[13] See for instance: Bauer, P., Fedotenkov, I., Genty, A., Hallak, I., Harasztosi, P., Martínez-Turégano D., Nguyen D., Preziosi, N., Rincon-Aznar, A., Sanchez-Martínez, M., (2020) 'Productivity in Europe – Trends and drivers in a service-based economy', EUR 30076 EN, Publications Office of the European Union, Luxembourg.

2. Internationalisation of research and development, regional integration and local innovation

2.1 Participants and collaborations

Since several years, JRC Unit I.1 carries out with DG Research and Innovation Unit A.1 the 'Innova Measure project'[14] which aim to develop and update composite indicators measuring R & I performance, improve the availability of evidence on start-up and scale-up of innovative firms, and study foreign investments in R & D. Within JRC I.1, Daniel Vertesy was the scientific coordinator of the project up to December 2019. Giacomo Damioli has been involved in the project since 2016 and succeeded Daniel as scientific coordinator in 2020. Maria del Sorbo, Giulio Caperna and Michele Aquaro are also part of the team. Vincent van Roy (JRC B.6) and Sara Amoroso (JRC B.3) have been involved in the design of several studies and provided in-depth advice during implementation. Formal collaborations external to the Commission have been established at different project stages with Davide Castellani (University of Reading), Balazs Lengyel (Hungarian Academy of Sciences) and Giovanni Marin (University of Urbino). Various workshops have been periodically organised in recent years in order to discuss the studies undertaken in the Innova project with experts from the Commission (mainly JRC and DG Research and Innovation), other institutions (the Organisation for Economic Co-operation and Development (OECD) and United Nations Conference on Trade and Development (Unctad) and academia.

2.2 Activity

Current understanding

The internationalisation of R & D business activities has seen an unprecedented increase in recent decades. Although multinational enterprises (MNEs) traditionally maintain the bulk of innovative activities in the home country (Patel and Pavitt, 1991; Patel and Vega, 1999; Belderbos et al., 2013), a large body of evidence indicates that today MNEs not only produce and sell but also increasingly innovate in foreign countries (Belderbos *et al.*, 2016; Dachs, 2017; Iversen et al., 2017). The economic geography literature provides the image of the globalised word economy as a set of 'local buzz' (Storper and Venables, 2004) connected by 'global pipelines' (Bathelt et al., 2004). Companies, MNEs in particular, are the key players shaping such connections, which serve as conduits for multidirectional knowledge flows between places (e.g. Iammarino and McCann, 2013; Song, 2014; Cano-Kollman et al., 2016). Although most interactions take place between geographically close actors, creating in some cases clusters (or buzz) with especially dense activity, cross-regional and cross-national connections (or pipelines) are key to allow combinations of different knowledge inputs and avoid cognitive lock-in (Boschma, 2005; Giuliani and Bell, 2005). Within this evolving context, there is a fierce, multilevel competition in which cities, regions and countries seek to attract innovative investments from abroad, expecting spillover effects to foster local productivity, growth and job creation. Previous studies assessed the role of local and national factors in attracting foreign direct investment (FDI). Existing evidence indicates that MNEs are attracted by the characteristics of narrowly defined territories (Nielsen et al., 2017), such as regions (e.g. Head and Mayer, 2004; Basile et al., 2009; Siedschlag *et al.,* 2013, Belderbos *et al.,* 2014, Belderbos and Somers, 2015) and cities (Goerzen *et al.,* 2013; Belderbos *et al.*, 2016; Cook and Pandit, 2018; Castellani and Lavoratori 2019a, b).

Research questions

Recent studies within various editions of the Innova Measure project looked at the location determinants, patterns of spatial diffusion and consequences on local innovation of innovative business investments directed to the EU and analysing different regions, origin and/or destination of such investments. In particular, Damioli and Vértesy (2017) study the factors affecting European regions' degree of attraction for MNEs choosing where to locate innovative FDI. Damioli et al (2019) assess the role of national and supranational factors in MNEs' location choices. Aquaro et al. (2020) investigate to what extent innovative (and non-innovative) cross-regional acquisitions (mergers and acquisitions (M & As)) contribute to the integration of European regions into a unified business area. Damioli and Marin (2020) study the effect of foreign greenfield and brownfield FDI on local patenting activities of receiving regions.

[14] https://ec.europa.eu/knowledge4policy/projects-activities/innova-project_en

Methodology / data used

The studies draw on data assembled from a variety of sources. Information on investments is gathered from the fDi Markets database maintained by fDi Intelligence (a division of the Financial Times Ltd) in the case of greenfield FDI, and from the Zephyr database maintained by Bureau Van Dijk in the case of M & As. Origin and destination locations of all investments have been geo-localised. The data set of investments has been complemented with various data sources (Eurostat, OECD, Cambridge Econometrics, etc.) providing information of interest at a local (regional or urban) level of granularity.

The studies hinge on different empirical methods with a core of regression techniques. Damioli and Vértesy (2017) use mixed logit regression models to study the importance of Nomenclature of Territorial Units for Statistics (NUTS) 2 regional features in the EU in attracting innovative greenfield FDI. Damioli et al. (2019) use nested logit regression models to assess the role of national and supranational borders (i.e. the EU and the North American Free Trade Agreement (NAFTA)) in the competition of functional urban areas (FUAs, cohesive agglomerations with 250 000+ population) to attract innovative greenfield FDI. Aquaro et al. (2020) combine social network and regression analysis techniques to study spatial patterns of innovative technologically intensive M & As (defined as those deals in which the target company already had a patent portfolio) versus non-innovative M & As involving the acquisitions and targeting of companies located in different regions, in order to understand to what extent these transactions facilitate economic integration. Damioli and Marin (2020) adopt an instrumental variable approach in a fixed-effects regression framework to study the effects of innovative greenfield and brownfield FDI on the patenting of receiving metropolitan regions (NUTS 3 or combinations of functionally cohesive NUTS 3 regions).

Findings

The study by Damioli and Vértesey (2017) confirms the findings of previous studies that key regional determinants of attracting FDI in R & D are the intensity of R & D expenditures, the availability and cost of skilled labour, technological and academic strength, and the technological concentration of destination regions (Belderbos et al., 2014; Belderbos and Somers, 2015; Siedschlag et al., 2013), as well as institutional factors (Ciriaci et al., 2016, 2019). Yet it shows that the corporate fiscal regime and the size of destination regions are the most important determinants. Moreover, the importance of regional characteristics varies across industries. MNEs operating in the pharmaceutical industry, for instance, are particularly responsive to private R & D expenditures and to the degree of technological strength and concentration (which acts as a deterrent of foreign entry), the strictness of labour market regulation and the restrictiveness of market regulation in the destination region. In contrast, MNEs operating in information and communication technology (ICT) services are more sensitive to public R & D expenditures, academic strength and R & D tax incentives.

Building on these findings, Damioli *et al.* (2019) show that European and North American urban agglomerations (FUAs) compete more with FUAs in the same country than with foreign ones. Their study extends previous evidence on the importance of national boundaries for location choices in Europe (Basile et al., 2009; Crescenzi *et al.*, 2014, 2016) to North America as well. They also provide novel evidence that European FUAs compete relatively more with other European ones than with North American ones. By contrast, North American FUAs compete similarly with FUAs in other North American countries and in European countries. The findings mean that, when MNEs have to choose where to locate an innovative greenfield project, they perceive the presence of the EU supranational bloc, but not the NAFTA bloc.

The study by Aquaro et al. (2020) shows that innovative technologically driven M & As are more international and concentrate to a higher extent in pairs of economically developed regions than non-innovative M & As. As in previous research focusing on innovative collaborations (Chessa et al., 2013; Tóth et al., 2018), both types of deals are fragmented among cohesive communities comprising entire countries or groups of neighbouring countries. Regional integration, measured as deals connecting different communities, increases during periods of intense M & A activity and is led by hub regions where the majority of M & A transactions occurs. The integration of communities is driven by acquisitions of technologically active target companies located in regions with high R & D intensity, and of technologically inactive targets located in wealthy regions with a plentiful supply of skilled labour.

The study by Damioli and Marin (2020) indicates a negative effect of inward innovative greenfield FDI on local patenting, while the effect of inward innovative M & A is negligible. The effect of greenfield FDI is particularly negative for regions with lower gross domestic product (GDP) per capita and smaller supplies of skilled human capital. Incumbent inventors suffer less than new emerging inventors in terms of patent productivity. Overall, the findings are consistent with the view that innovative greenfield FDI disrupts local networks of inventors and increases the cost of doing R & D for incumbent local companies. These negative effects are only partly compensated for by the local availability of adequate skills and absorptive capacity.

Contribution to science and policy, and practical implications

Overall, the findings of the studies indicate that EU-level, national and local policies have some room to create favourable conditions for attracting FDI in R & D. Besides fostering R & D expenditures, and scientific and technological strength, they also need to take into consideration the specificities of FDI in relation to regional industrial structures. Yet the beneficial spillover effects on the local economies of receiving areas, often assumed in previous studies, require a closer empirical scrutiny. The spatial diffusion of innovative FDI flows signals the presence of outstanding hub regions or urban agglomerations where the majority of foreign and cross-regional innovative private investments takes place and concentrates, and the incomplete yet increasing integration of EU regions. On the one hand, spatial concentration creates concerns, as increasing regional inequality in the EU is thought to damage social cohesion, political stability and economic growth (Iammarino et al., 2019). On the other hand, hub regions bridge distant locations and fragmented innovation systems, positively contributing to the process of EU integration in a common economic and innovative area.

2.3 Limitations, follow-up and further collaborations

A general limitation applying to all studies is due to the nature of the investment data sets, which allow one to observe the monetary value of only a minority of investments. As a result, all studies use the number of investments received as a proxy for local inflows. An additional limitation is that regional attractiveness and performance are limited to the EU, whereas it would be helpful to extend the analysis outside the EU's borders in order to benchmark the EU against relevant partners. Damioli et al. (2019) make an initial attempt to move in this direction, although at the expense of focusing on a set of internationally comparable urban centres, which implies losing rural areas and less populous cities. Increasing international scope while ensuring fine-grained spatial granularity of functionally cohesive local areas (going beyond administrative borders) remains a challenge for future research to address.

As the current Innova project is approaching its conclusion, JRC Unit I.1 and DG Research and Innovation Unit A.1 are discussing the scope of the next edition. The research idea most directly related to the studies briefly reviewed here is to study the effect of innovative FDI on local outcomes other than patenting. Outcomes of interest currently debated are the labour market effects of inward and outward innovative FDI, in particular in relation to employment creation and skills polarisation.

JRC Unit I.1 is open to considering opportunities for collaboration within and beyond the JRC in the framework of the next Innova project.

References

Aquaro, M., Damioli, G. and Lengyel, B. (2020), *Innovative mergers and acquisitions and the integration of European regions*, EUR 30489 EN, Luxembourg, Publications Office, doi:10.2760/52361, JRC122436.

Basile, R., Castellani, D. and Zanfei, A. (2009), 'National boundaries and the location of multinational firms in Europe', *Papers in Regional Science*, Vol. 88, No 4, pp. 733–748.

Bathelt, H., Malmberg, A. and Maskell, P. (2004), 'Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation', *Progress in Human Geography*, Vol. 28, No 1, pp. 31–56.

Belderbos, R. and Somers, D. (2015), 'Do technology leaders deter inward R & D investments? Evidence from regional R & D location decisions in Europe', *Regional Studies*, Vol. 49, No 11, pp. 1805–1821.

Belderbos, R., Leten, B. and Suzuki, S. (2013), 'How global is R & D? Firm-level determinants of home-country bias in R & D', *Journal of International Business Studies*, Vol. 44, No 8, pp. 765–786.

Belderbos, R., Van Roy, V., Leten, B. and Thijs, B. (2014), 'Academic research strengths and multinational firms' foreign R & D location decisions: Evidence from R & D investments in European regions', *Environment and Planning A*, Vol. 46, No 4, pp. 920–942.

Belderbos, R., Sleuwaegen, L., Somers, D. and De Backer, K. (2016), 'Where to locate innovative activities in global value chains: Does co-location matter?', *OECD Science, Technology and Industry Policy Papers*, No 30, Paris, OECD Publishing.

Boschma, R. (2005), 'Proximity and innovation: A critical assessment', *Regional Studies*, Vol. 39, pp. 61–74.

Cano-Kollmann, M., Cantwell, J., Hannigan, T. J., Mudambi, R. and Song, J. (2016), 'Knowledge connectivity: An agenda for innovation research in international business', *Journal of International Business Studies*, Vol. 47, pp. 255–262.

Castellani, D. and Lavoratori, K. (2019a), 'Location of R & D abroad: An analysis on global cities', in Capik, P. and Dej, M. (eds), *Relocation of Economic Activity*, Cham, Springer.

Castellani, D. and Lavoratori, K. (2019b), 'The lab and the plant: Offshore R & D and co-location with production activities', *Journal of International Business Studies*.

Chessa, A., Morescalchi, A., Pammolli, F., Penner, O., Petersen, A. M. and Riccaboni, M. (2013), 'Is Europe evolving towards an integrated research area?', *Science*, Vol. 339, No 6120, pp. 650–651.

Ciriaci, D., Grassano, N. and Vezzani, A. (2016), 'Regulation, red tape and location choices of top R & D investors', *JRC Working Papers on Corporate R & D and Innovation*, No 2016-01, Seville, European Commission, Joint Research Centre.

Ciriaci, D., Grassano, N. and Vezzani, A. (2019), 'Regulations and location choices of top R & D investors worldwide', *Structural Change and Economic Dynamics*, Vol. 49, pp. 29–42.

Cook, G. and Pandit, N. R. (2018), 'Cities and international business: insights from crossdisciplinary perspectives', in Cook et al (eds), *The Routledge Companion to the Geography of International Business*, London, Routledge.

Crescenzi, R., Pietrobelli, C. and Rabellotti, R. (2014), 'Innovation drivers, value chains and the geography of multinational corporations in Europe', *Journal of Economic Geography*, Vol. 14, No 6, pp. 1053–1086.

Crescenzi, R., Pietrobelli, C. and Rabellotti, R. (2016), 'Regional strategic assets and the location strategies of emerging countries' multinationals in Europe', *European Planning Studies*, Vol. 24, No 4, pp. 645–667.

Dachs, B. (2017), 'Internationalisation of R & D: A review of drivers, impacts, and new lines of research', *Asian Research Policy*, Vol. 8, pp. 17–39.

Damioli, G. and Marin, G. (2020), *The Effects of Foreign Entry on Local Innovation*, EUR 30490 EN, Luxembourg, Publications Office, doi:10.2760/449310, JRC122433.

Damioli, G. and Vértesy, D. (2017), *The Seductive Power of Irish Rain: Location determinants of foreign R & D investments in European regions*, JRC technical report, EUR 28605 EN, Luxembourg, Publications Office.

Damioli, G., Vertesy, D. and Castellani, D. (2019), *The ERA of International R & D Investments*, EUR 29609 EN, Luxembourg, Publications Office.

Giuliani, E. and Bell, M. (2005), 'The micro-determinants of meso-level learning and innovation: Evidence from a Chilean wine cluster', *Research Policy*, Vol. 34, pp. 47–68.

Goerzen, A., Asmussen, C. G. and Nielsen, B. (2013), 'Global cities and multinational enterprise location strategy', *Journal of International Business Studies*, Vol. 44, No 5, pp. 427–450.

Head, C. K. and Mayer, T. (2004), 'Market potential and the location of Japanese investment in the European Union', *Review of Economics and Statistics*, Vol. 86, pp. 959–972.

Iammarino, S. and McCann, P. (2013), *Multinationals and Economic Geography: Location, technology, and innovation*, Cheltenham, United Kingdom: Edward Elgar.

Iammarino, S., Rodriguez-Pose, A. and Storper, M. (2019), 'Regional inequality in Europe: Evidence, theory and policy implications', *Journal of Economic Geography*, Vol. 19, pp. 273–298.

Iversen, E., Dachs, B., Poti, B., Parimal Patel, P., Cerulli, G. Spallone, R., Zahradnik, G., Knell, M., Scherngell, T. and Lang, F. (2017), *Internationalisation of business investments in research and development and analysis of their economic impact (BERD Flows)*, Brussels, European Commission.

Nielsen, B. B., Asmussen, C. G. and Weatheralld, C. D. (2017), 'The location choice of foreign direct investments: Empirical evidence and methodological challenges', *Journal of World Business*, Vol. 52, pp. 62–82.

Patel, P. and Pavitt, K. (1991), 'Large firms in the production of the world's technology – an important case of non-globalization', *Journal of International Business Studies*, Vol. 22, No 1, pp. 1–21.

Patel, P. and Vega, M. (1999), 'Patterns of internationalisation of corporate technology: location vs. home country advantage', *Research Policy*, Vol. 28, Nos 2–3, pp. 145–155.

Siedschlag, I., Smith, D., Turcu, C. and Zhang, X. (2013), 'What determines the location choice of R & D activities by multinational firms?', *Research Policy*, Vol. 42, No 8, pp. 1 420–1 430.

Song, J. (2014), 'Subsidiary absorptive capacity and knowledge transfer within multinational corporations', *Journal of International Business Studies*, Vol. 45, No 1, pp. 73–84.

Storper, M. and Venables, A. J. (2004), 'Buzz: face-to-face contact and the urban economy', *Journal of Economic Geography*, Vol. 4, pp. 351–370.

Tóth, G., Juhász, S., Elekes, Z. and Lengyel, B. (2018), 'Inventor collaboration and its persistence across European regions', arXiv preprint arXiv:1807.07637.

3. Research and innovation, and taxation

3.1. Participants and collaborations

The participants and collaborators of this work were the following. María T. Álvarez-Martínez (JRC B2), Salvador Barrios (JRC B2), Diego d'Andria (JRC B2), Maria Gesualdo (JRC B2), Jonathan Pycroft (JRC B2), Gaëtan Nicodème (DG Taxation and Customs Union), Agnieszka Skonieczna (DG Taxation and Customs Union), Dimitrios Pontikakis (JRC B3), Antonio Vezzani (JRC B3), Annette Alstadsaeter (School of Economics and Business, Norwegian University of Life Sciences).

3.2. Activity

Current understanding

R & D contributes to long-term economic growth through the improvement of productivity and competitiveness. In order to support and increase R & D investment, many governments are eager to attract foreign investors by reducing corporate income tax (CIT) rates, and more specifically by introducing **R & D provisions** and/or **patent boxes**. The latter are favourable regimes for income generated with intellectual property (IP) that have spread mainly in developed countries since 2000. However, the effects of these instruments on the economy may differ from their expected results. The reduction of CIT could spur investment and growth, but it is detrimental to tax revenues, and triggers increases in other taxes to meet fiscal policy objectives. On the other hand, R & D provisions and patent boxes may not be enough to raise R & D levels as a percentage of GDP, and additional measures could be needed. All these issues, together with the idea that R & D activities are more common in multinationals with high levels of intangible assets, have led to a deeper analysis of taxation on digital firms or **digital taxation**. The OECD proposals on the taxation of the digital economy aim to revise profit allocation and nexus rules to better align the income generated by multinationals with the taxes they pay, given the challenges of the dematerialisation of the economy.

There are two pillars proposed by the OECD.

Pillar 1: The reallocation of taxing rights and the redesign of profit allocation and nexus rules are based on where the value is created. This reallocation is based on what is called the non-routine or residual profit split approach, whereby the share of residual profits would rely on pre-agreed percentages of routine or normal profits.

Pillar 2: The profits of multinationals are subject to a minimum tax rate. Our main interest is in evaluating **the impact of Pillar 1**.

Research questions

There are several questions related to the previous research topics. What is the rationale for including R & D allowances and what is the amount needed? What are the ultimate effects of the IP box policies? What are the potential effects of the OECD proposal (Pillar 1: profit reallocation and nexus rules) on the taxation of the digital economy? In what follows, we present the answers to all these questions.

Methodology / data used

In the analysis of **R & D allowances**, the study is performed by applying different subsidies that would serve to keep the current levels of expenditure on R & D or to increase them relative to GDP. The generosity of the treatment of R & D is measured using B-indexes, which are summary indicators of the implicit R & D tax subsidies and allow international comparisons of different tax regimes. First, the B-indexes are transformed into estimates of the user costs. Then we multiply the pre- and post-reform differences in user costs by the elasticity of businesses R & D with respect to changes in the user cost of R & D. As the elasticity of estimates provided in the literature varies considerably, the analysis results in a plausible range of impacts.

To evaluate the effect of **patent boxes**, it is necessary to identify first what IP rights qualify for the patent box, the tax treatment of existing patents and the treatment of acquired patents together with other additional information. The data set is novel and relatively rich, encompassing more than 30 countries for three productive sectors. This is a significant improvement on the existing literature.

Finally, in relation to **digital taxation**, and more precisely Pillar 1 in the OECD proposal, we extended the computable general equilibrium corporate taxation (CORTAX) model (Álvarez-Martínez et al., 2016) to include the R & D sector. This new version captures the effects of both general taxation and specific tax incentives. We can better simulate multinationals' profit shifting and relate them to the existence of intangible assets. In this way, we capture an additional channel through which policy reforms of corporate taxation can affect the economy. The new sector is included, modifying the production structure. R & D is produced using highly skilled labour and capital, and its output is used as an intermediate good by the other productive sector. There are also adjustments in the equations of transfer pricing, corporate tax base, returns to the fixed factor, and marginal products of labour and capital. We allow for two coexistent tax regimes, depending on the type of profits (i.e. routine and non-routine). Current national rules apply to routine profits, while non-routine profits are consolidated and reallocated across countries according to allocation keys. We consider alternative values for the share of residual profits in total profits (10, 20, 50 and 80 %). The reallocation of taxing rights on the share of non-routine profits is determined by an apportionment formula.

Findings

The study on **provisions to support R & D investment** finds that EU Member States will need to engage in complementary interventions in their national innovation systems to boost R & D after the implementation of a corporate taxation reform such as the Common Consolidated Corporate Tax Base (CCCTB), originally proposed in 2011. This reform, without any bonus allowance for R & D, would result in a significant reduction in R & D. An allowance of 33 % would be needed.

In the analysis of **patent boxes**, there are two sets of results. On the one hand, the presence of an IP box in a country reduces the negative effects that general taxation has on patents registered in that particular country. However, these effects are heterogeneous depending on sector, value of inventions and scope, with a stronger effect when the IP box benefit is extended to pre-existing patents or IP rights.

In terms of **digital taxation**, the simulations show that the different shares of routine and non-routine profits have small effects compared with the baseline. Ireland, Luxembourg, the Netherlands and the United Kingdom have CIT revenue losses, while Belgium and France increase their CIT revenues. On average, there is a slight fall in CIT revenue. In the case of China, tax revenues increase in all scenarios. These results are the consequence of new combinations of allowances due to consolidation, causing a narrowing of the tax base. The use of a formula apportionment to reallocate taxing rights that accounts for the number of employees may explain the results for China, which has firms with many workers and large contributions to worldwide production. Alternative allocation keys may be used in future simulations.

Contribution to science and policy, and practical implications

Tax policy has been considered a good instrument to stimulate investment and correct the market tendency to underinvest in R & D activities. The current research projects undertaken at Unit B2 in collaboration with other units and DGs contribute to policy discussion and show significant socioeconomic effects. The reform of CCCTB and R & D benefits introduced in 2011 would present a level playing field within the EU, saving on compliance costs and removing distortions that impede the functioning of the single market. However, additional allowances would be necessary. This information has been very useful, since the CCCTB reform from 2016 provides for an allowance; consequently, this study is relevant to DG Taxation and Customs Union, national governments and general public discussion.

Patent boxes reduce the impact of high effective tax rates, which lower the number of patents registered in a given country. If there is a harmonisation of taxes or a change in the nexus rules at the level of the EU or the OECD, it will dampen the dominant effects of the tax advantage of the patent box regime on patent locations while encouraging local *invertorship*[15]. These results are also relevant to DG Taxation and Customs Union and its proposal on CCCTB reform.

The size of the digital sector in a country tends to be negatively related to the changes in CIT revenues. This is more pronounced the larger the share of non-routine profits. The results of evaluating digital taxation are very novel, since they estimate both direct and indirect general equilibrium effects of the most recent proposal of the OECD, which is very relevant to DG Taxation and Customs Union and the EU Member States.

[15] 'Inventorship' refers to who conceived the invention. Unless a person contributes to the conception of the invention, they are not an 'inventor'.

3.3. Limitations, follow-up and further collaborations

Although these studies are very detailed and have gone through several robustness checks, there is room for improvement. In the evaluation of R&D allowances, an important limitation is that it relies on general elasticities hailing from a varied and ambiguous empirical record. More detailed analysis is needed. It will also be desirable to take into account the general equilibrium effects and firms' heterogeneity.

In extending CORTAX for digital taxation, the model can be improved in several ways. A key adjustment would be to include knowledge spillovers to capture the fact that firms both within the country and outside are able to learn from the innovative firms. In the calibration of data, we would also like to extend the boundary of the knowledge sector to include non-R&D innovation activities and outcomes.

The future lines of research will be followed with the collaboration of other units, such as JRC B6 in the collection of data and exploitation of international databases, and other units in DG Taxation and Customs Union, universities and research institutes.

Reference

Álvarez-Martínez, M.T., Barrios, S., Bettendorf, L., d'Andria, D., Gesualdo, M., Loretz, S., Pontikakis, D. and Pycroft, J., (2016), 'A new calibration for CORTAX: A computable general equilibrium model for simulating corporate tax reforms', *JRC Working Papers on Taxation & Structural Reforms*, No. 2016-09, Seville, Joint Research Centre (https://ideas.repec.org/p/ipt/taxref/201609.html).

4. Global industrial research and innovation analyses

4.1 Participants and collaborations

The core team is in JRC B3, working on industrial R & I[16], in two main areas: understanding corporate R & I investment, and complexity analysis for industrial competitiveness and R & I (the latter together with JRC B5). The team succeeded in increasing collaboration with its sister units B6, C4 and C7 on joint patent and firm-level analyses and on content related to the low-carbon energy and transport sectors.

4.2 Activity

Current understanding and research questions

The objective is to generate science-based evidence to support policymaking and the response to changing policy needs in the above initiatives, by monitoring, analysing and benchmarking the global industrial players in their R & D investments and strategies. For this purpose, the project developed an approach to increase the meaningfulness of the monitoring tool, together with additional analyses relevant to the policy agenda. On the Green Deal objectives, the project aimed to better understand how **'corporate R & I for sustainable competitiveness' can contribute to prosperity** as a core component of Europe's Green Deal, the global SDG agenda and the new EU industrial strategy (European Commission, 2020).

The project is able to cover **top-down, actor-based and quantitative analyses** in support of the new policy agenda. This constitutes a **unique and key Commission capacity** towards the transition of the R & I and industry policies to competitive sustainability. This uniqueness stems from the fact the approach proposed here starts from the companies/industries that invest high amounts in R & D, according to the EU R & D Investment Scoreboard (Hernández *et. al.,* 2019) , and develop technological solutions for the green policy agenda'. The new tools added and developed here ensure a technology assessment approach to companies not covered in the scoreboard. Such companies/industries are highly concerned with green/sustainability issues because they are highly energy- or resource-intensive. The approach also supports the EU taxonomy on sustainable finance in using the latest available financial data from companies, adding significant elements of directionality, and thus allowing a better understanding of the sustainable finance taxonomy related to global corporate R & I investment and the derived industrial competitiveness. Therefore, improvements of such taxonomy can be achieved by exploiting the results from the present project.

The project also convers **place-based aspects** highly relevant to the policy agenda, e.g. how, why and where companies in selected sectors deploy their R & D and innovation activities beyond the general allocation to a company headquarters. This is of particular relevance to understanding geographical distribution in Europe and to the assessment of Member States' (**European Semester**) and regions' (**smart specialisation**) industrial R & D and innovation policies, and the design and review of regulations and policies affecting industrial R & I. It also makes it possible to detect early trends and identify potential drivers for firm creation and growth, thus informing policymakers of the conditions and incentives needed to attract high-value and knowledge-intensive activities to the European economy.

Methodology / data used

The work was carried out in the 'Global industrial research & innovation analyses' (Gloria) project in close collaboration with DG Research and Innovation. It has ensured the continuation of collection of high-quality data on major corporate R & D investors, covering a sample of companies representing about 90 % of all the R & D investments financed by the business sector worldwide. The data set has been enriched with extremely valuable data on subsidiaries (overall, the total company sample includes more than 600 000 individual companies) and with novel data on the IP portfolios (patents, publications and trademarks) of these global leading players. These data are open to the public (the data on IP portfolios have been jointly developed with the OECD and are available online as the COR&DIP Database) and cover more than 12 years. This offers enormous possibilities for analysis and better understanding of major industrial innovation activities and dynamics. Based on this data collection, the project has delivered two new editions of the EU R & D Investment Scoreboard and two of the EU Industrial R & D Survey. Detailed summaries of the reports are available on the relevant project web page. The reports have continued to receive attention from

[16] https://iri.jrc.ec.europa.eu/home/

policymakers, as shown by the number of press releases and statements from Commissioners responsible for R& I. Both the survey and the scoreboard show that major industrial players with headquarters in Europe consider R & D and innovation to be crucial strategic investments to keep and improve their current and future competitiveness. The scoreboard shows an intensifying race for global technological leadership over the past decade. EU companies are maintaining leadership in sectors such as automobiles, traditional health, and aerospace and defence, but reducing their weight in ICT industries and biotech-health. US companies have reinforced their position in high-tech sectors, especially in ICT services and health. Chinese companies have substantially increased, albeit from a lower base, their global shares in ICT industries and in low-tech sectors.

The 2020 editions of the scoreboard and survey were adapted to the new policy priorities. The 2020 scoreboard assesses the technological potential of European companies in the global context regarding green patents and SDG contributions, with a specific chapter on climate change mitigation technologies. Most green patents owned by the scoreboard companies (about 80 %) are in companies headquartered in Japan (30.9 %), the United States (26.8 %), Germany (11.8 %) and South Korea (10.5 %). EU companies show comparative advantages in most green technologies, except ICT applications for energy. Toyota has most green patents, but Bosch, Volkswagen, Airbus and Rolls-Royce (in numerical order) are EU firms in the top 25 global companies by number of green patents. The global automotive sector accounts for 13 % of all the global Scoreboard companies' patents, mostly in current automotive technologies, but an increasing proportion relate to green technologies, including electric and autonomous vehicles and newer components such as novel batteries and fuel cells. EU companies hold 35 % of these patents, including 26 % of green patents, and appear highly diversified and competitive in most technological fields. However, in green technologies related to hybrid cars, batteries and fuel cells, their Japanese counterparts are leading the race. The software, technology hardware, electronics and chemicals sectors are catching up on the automotive sector in numbers of patents filed. This is challenging EU companies, whose lead in the automotive sector may be eroded as digital technologies take a higher proportion of the value added in the automotive sector with the advent of new developments such as electric self-driving cars fitted with more electronics and communications accessories.

The 2020 survey included questions on sustainability strategies in companies, the impact of COVID-19 and competition policy.

Findings

The GLORIA project has further exploited and analysed the data collected in view of gathering empirical evidence to support policymaking in the areas of R & I and industrial policy based on the priority areas agreed between the JRC and DG Research and Innovation for the project. Some highlights from the results of our analyses are shown below.

Distribution of industrial research & innovation activities: An application of the technology readiness levels (Dosso *et al.,* 2019)

The technology readiness levels (TRLs) approach is relevant to mapping the functional decomposition of companies' R & D value chains. TRLs matter for corporate location choices.
Knowing what distinct types of R & D and R & I activities stay, go and come back in EU territories – and why – is central for policies supporting local industrial and innovation ecosystems and clusters, and for identifying and integrating these ecosystems and clusters into strategic value chains. Fast-developing local strengths of Asian countries such as China, Japan and South Korea in the automotive sector, and in electronics and related fields, are shaping companies' geographical distribution of R & D & I activities. Although the EU has strong value chains in, for example, the automotive (relying on a consolidated industrial network for combustion engines) and pharmaceutical (highly skilled labour force and strong research institutions) sectors, corporate R & D and R & I investments in novel emerging technologies are finding their way to Asia.

What are the policy options? A systematic review of policy responses to the impacts of robotisation and automation on the labour market (Cséfalvay, 2019).

Three main policy responses to the labour market challenges posed by robotisation and automation have emerged in the research literature. The first is 'taxing robots' and using this revenue to introduce a basic income that could offset the negative impacts of replacing humans with robots. The second option highlights that owning robots will make it possible to create and share in this new source of wealth. The third focuses on strengthening the comparative advantages, the creativity, and the social intelligence of humans that robots will never be able to match. All of these policy responses are supported by economic rationales and research findings but a systematic review shows that all of them raise further questions and challenges that should be carefully investigated in order to choose the right path. This paper offers a comprehensive overview of these questions. Furthermore, in a broader sense these policy options—redistributing the benefits of technological changes, increasing accesses to the benefits and utilization of changes, and supporting the individual and institutional adjustment to changes are relevant to every technological transformation. Hence, the lessons that are drawn from the current discussion of policy options driven by specific technologies, robotisation, and automation might serve as a precursor to potential policy responses triggered by other technologies.

Labor mobility from R&D-intensive multinational companies: Implications for knowledge and technology (Holm *et al.,* 2019)

Private- sector R & D is largely concentrated in a few multinational companies (MNCs), which thus play an important role in the creation of knowledge and technology in the economy. The mobility of labour between these firms and the rest of the economy is therefore an important mechanism for the diffusion of knowledge. This paper analyses in detail the flow of labour between firms, with specific emphasis on flows to and from R & D- intensive MNCs. Using linked employer–-employee data for Denmark, we match employees moving from R & D- intensive MNCs withto other employees switching jobs. We find that employees are more inclined to move between R & D- intensive MNCs and their subsidiaries rather than between these firms and other firms in the economy. This is particularly true offor highly skilled employees. Our results suggest that other domestic firms are to a larger great extent kept out of the 'knowledge spill over' loop, which provide them withso they have fewer opportunities to learn from the R & D-intensive MNCs. In other words, R & D-intensive MNCs and their subsidiaries form a kind of sub labour market within the national labour market: employees exhibit higher mobility within this group of firms than between this group and the rest of the labour market [17].

Regulations and technology diffusion in Europe: the role of Industry dynamics

Together with DG Research and Innovation A1, we drafted a chapter of the flagship report *Science, Research and Innovation Performance of the EU* (SRIP report). Using a data set compiled from a variety of sources, it investigates the role of labour, capital and product market regulatory frameworks in the technology diffusion process, and also accounts for the role of business dynamism in mediating and moderating the impact of regulation on technology diffusion. The results suggest the following.

- A one-size-fits-all regulatory model does not lead to faster technology diffusion. Regulations has to account for specific characteristics of the market and the structure of the sector.
- While excessive product market regulation tends to hinder technology diffusion, this only holds true in industries with vigorous business dynamism and high churn rates, in which innovation is driven by new entrants.
- A similar argument holds for labour market regulation, suggesting a more prudent view than merely advocating *tout court* deregulation of labour market relationships.
- Human capital and access to finance are confirmed as cross-cutting drivers of technology catch-up and diffusion. While policies in this domain do not specifically address diffusion directly, they are key in increasing the adoption rate of innovations, enabling local (research and) innovation systems to produce, absorb and implement new knowledge, keeping pace with global technological change.

Contribution to science and policy, and practical implications

Collaboration and dissemination in the science–policy–industry nexus is at the top of the agenda for achieving impact with the project results. In the past 2 years, the team organised three workshops in Brussels related to the project, participated in around 15 international scientific conferences, and undertook around 70 trips to participate in meetings with stakeholders in and outside the EU. At the team's invitation, around 20 scientists and policymakers have presented their work in seminars at the JRC facilities in Seville.

Furthermore, the results are disseminated through the JRC working paper series, which includes a review process by an editorial board. The number of publications provides an image of the very high productivity of the team. In the reporting period, a total of 7 technical reports (including the annual scoreboard and survey), 12 working papers, 6 policy briefs, 6 articles in scientific peer-reviewed journals and 3 research collaborations were produced. The industrial R & D investment scoreboards are continuously among the top three most

[17] The JRC has a dedicated work stream dealing with 'Learning and Skills for the Digital Era', including employment and robotics – (for more information see: https://ec.europa.eu/jrc/en/research-topic/learning-and-skills)

downloaded publications of the JRC (about 35 000 downloads per year), followed by the surveys (about 5 000 downloads per year), working papers and policy briefs (between 500 and 1 500 downloads per year).

Regarding impact in official policy documents, the project has achieved citations of its output in Commission communications and staff working documents, contributed to the internal preparatory work for them, contributed to around 25 Commission internal briefings and presentations, and policy documents by DG Research and Innovation, and resulted in joint activities and publications with the OECD and the World Intellectual Property Organization (WIPO).

The progress also included the organisation of thematic GLORIA workshops in which the results of the research (presented in a non-academic format, such as policy briefs) are validated by other experts and presented to policymakers and industrialists. Three GLORIA workshops were organised in the reporting period on 'Competition, R & D and innovation dynamics', 'Global corporate value chains and innovation networks in the fourth industrial era: New models of production and work organisation', and 'Corporate R & I towards Europe's Green Deal: An opportunity for new business and prosperity?'

All materials (summary reports, presentations, list of participants, agendas and background documents) are available at the project website (https://iri.jrc.ec.europa.eu/home/).

4.3 Limitations, follow-up and further collaborations

Limitations stem from the availability and limitations of data, on the one hand, and additional expert capabilities, on the other. The approach of this project is actor-based, using large databases, whose classifications do not always reflect policy options. This limitation is tackled by collaborating closely with policy DGs in the publication of key reports, such as the scoreboard and survey. This project engages in additional collaborations with the OECD, the European Investment Bank and WIPO..

Bibliography

Cséfalvay, Z. (2019), 'What are the policy options? A systematic review of policy responses to the impacts of robotisation and automation on the labour market', *JRC Working Papers on Corporate R & D and Innovation*, No 02/2019, Joint Research Centre.

Dernis, H., Gkotsis, P., Grassano, N., Nakazato, S., Squicciarini, M., van Beuzekom, B., Vezzani, A. (2019), *World Corporate Top R & D investors: Shaping the future of technologies and of AI – A joint JRC and OECD report*, EUR 29831 EN, Luxembourg, Publications Office, doi:10.2760/472704, JRC117068.

Dosso, M., Potters, L. and Tübke, A. (2019), 'Distribution of industrial research & innovation activities: An application of technology readiness levels', Industrial R & I – JRC Policy Insights, January.

Grassano, N., Hernandez Guevara, H., Tuebke, A., Amoroso, S., Dosso, M., Georgakaki, A. and Pasimeni, F. (2020), *The 2020 EU Industrial R & D Investment Scoreboard*, EUR 30519 EN, Luxembourg, Publications Office, doi:10.2760/655526, JRC123317.

Hernández, H., Grassano, N., Tübke, A., Amoroso, S., Csefalvay, Z. and Gkotsis, P. (2019), *The 2019 EU Industrial R & D Investment Scoreboard*, EUR 30002 EN, Luxembourg, Publications Office, doi:10.2760/04570, JRC118983.

Holm, J. R., Timmermans, B., Østergaard, C. R., Coad, A., Grassano, N. and Vezzani, A. (2019), 'Labor mobility from R & D-intensive multinational companies: Implications for knowledge and technology transfer', *Working Papers on Corporate R & D and Innovation*, No 06/2019, Joint Research Centre.

Moncada-Paternò-Castello, P. and Grassano, N. (2020), 'The EU vs US corporate R & D intensity gap: Investigating key sectors and firms', *Working Papers on Corporate R & D and Innovation*, No 02/2020 – JRC120008, Seville, Joint Research Centre.

Potters, L. and Grassano, N. (2019), *The 2019 EU Survey on Industrial R & D Investment Trends*, EUR 30005 EN, Luxembourg, Publications Office, doi:10.2760/200895, JRC119026.

Potters, L. and Grassano, N. (2020), *The 2020 EU Survey on Industrial R & D Investment Trends*, EUR 30518 EN, Luxembourg, Publications Office, doi:10.2760/003388, JRC123333.

5. Economic complexity for industrial innovation and competitiveness

5.1. Participants and collaborations

The participants to this work were E. Pugliese, L. Napolitano, D. Diodato, A. Tübke (JRC Unit B.3); A. Tacchella, R. Marshinski (JRC Unit B.5); the collaborations were peers from the JRC Unit B.6, Institute for Complex Systems (Italian National Research Council), International Finance Corporations (World Bank Group), United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology.

5.2 Activity

Current understanding and research question

Since January 2019, the JRC has built up the **economic complexity framework** to address territorial development, industrial innovation and competitiveness. These are closely intertwined through the necessary resources (data, algorithms, techniques) and science-to-policy outputs: industry is central to the innovation system, at the same time a driver of and driven by innovation, and key for the green and digital transformations.

Economic complexity is a natural continuation of evolutionary and institutional economics, leveraged by network science, complex systems and dynamic systems. It makes it possible to separate random noise present in large data sets from the underlying signal, and thus to extract robust quantitative information. The **geolocalisation feature** ensures consistency at different levels, allowing one to zoom into more granularity (from global to national, to regional, to local). The **time component** reveals the non-linear complex co-evolution of its components, providing **highly relevant inputs on cross-cutting themes** of competitiveness and innovation.

The aim of this activity was to use complex system techniques to investigate the country- and regional-level capabilities in specific sectors and markets, in all the layers of the innovation systems. In this respect, the activity aimed both to create closer ties with European academic experts and to build capabilities to develop economic fitness and complexity analysis internally, both by consolidating our data structure and by building our internal capabilities.

Methodology / Data used

The external activities developed through various external contracts. A contract with the Consiglio Nazionale delle Ricerche, Italy, had three main aims. The first was to help the team build the data required. Second, it aimed to give us standardised analyses to be used as comparisons for our own efforts. Third, the Consiglio Nazionale delle Ricerche provided two training sessions that helped us build capabilities in the JRC and created contacts with other interested groups. A second contract, with the United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology, Netherlands, was by contrast intended to explore alternative options and techniques that had not yet been developed in the academic literature. Finally, a contract with Dr Angelica Sbardella, Sant'Anna School of Advanced Studies, Italy, provided us with detailed information on green technology and its role in the overall innovation system.

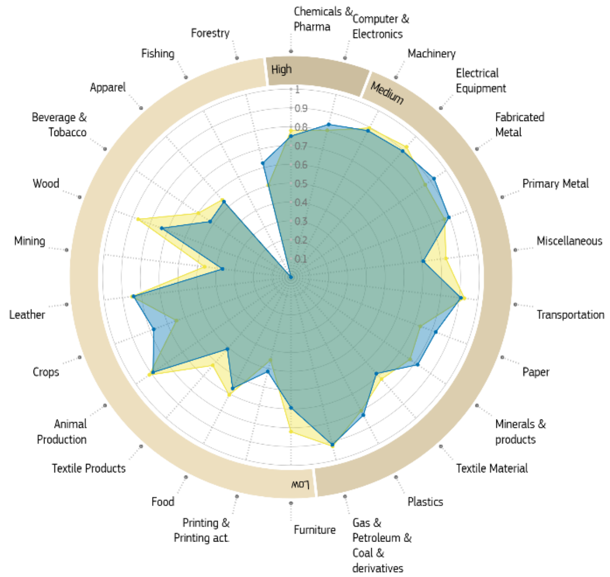

Figure 5.1 Export capabilities of Slovakia in different industrial sectors. Yellow, the situation in 2012; blue, the situation in 2018. Source: https://ec.europa.eu/jrc/sites/jrcsh/files/jrc122086.pdf

Internally, we worked on three aspects. First, we worked on our digital infrastructure: we set up the Jupyterhub server, which works as a computation server for all our activities in parallel computing, and we worked on data cleaning, extraction, transformation and matching. Second, through dissemination and dialogue with interested stakeholders we defined potentially interesting questions and aroused interest in our products. Finally, we developed and tested our methodology, and produced two reports (Pugliese and Tübke, 2019; Pugliese and Tacchella, 2020) to showcase the analyses we are now able to produce internally.

Findings

Thanks to these steps we developed complexity analyses on territorial competitiveness (productive structure and growth trajectories), technological capabilities and their combinations, and performed projections into the future, producing **development trajectories and GDP forecasts**, **industrial sector forecasts**, and mapping and export market analysis of the **regional innovation system**.

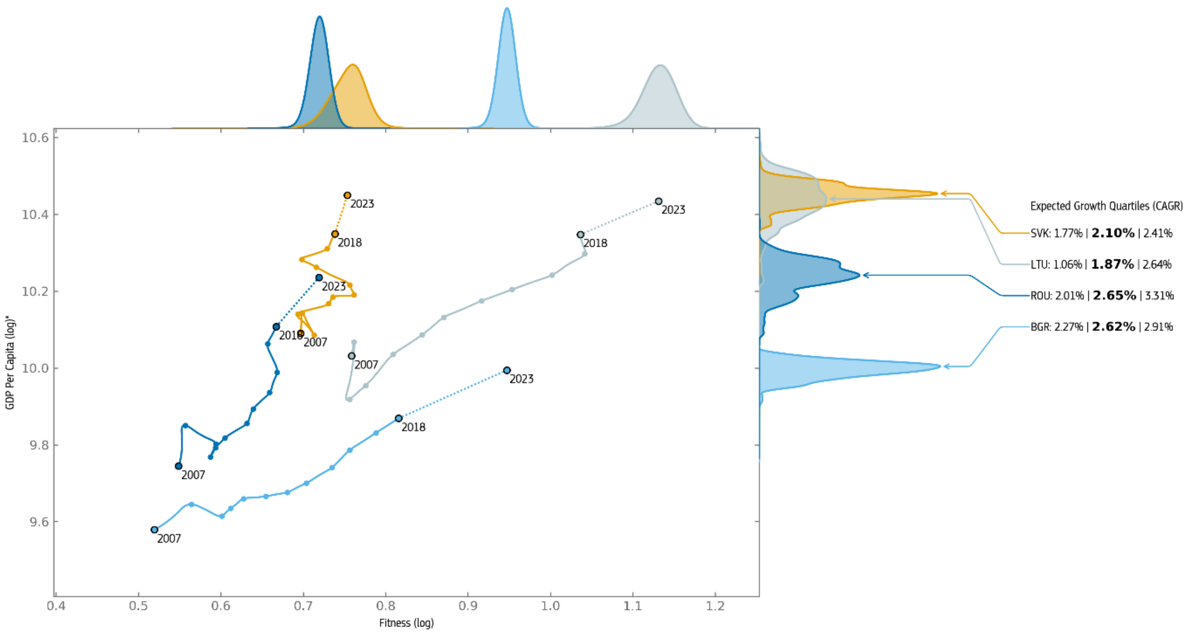

Figure 5.2 GDP growth trajectory and forecast of Slovakia compared with a few EU countries.
Source: https://ec.europa.eu/jrc/sites/jrcsh/files/jrc122086.pdf

These are **different from traditional exercises**, and able to forecast medium-term (5 years) GDP growth up to 25 % more precisely than (International Monetary Fund) mainstream approaches, (Tacchella *et al.*, 2018) calculate export-product progression probabilities, and provide regional technology-export fitness combinations, showcased in infographics for each EU Member State.[18]

As an example, in our pilot work on Slovakia we identified the transport industry as a key sector in which Slovakia has unexploited potential, in particular in railway-related markets (Figure 5.3). This spans from electronics (signals, traffic control software) to transport hardware (railway wagons). The analysis goes deeper, identifying the best-suited regions in Slovakia to enter each of the related submarkets (mostly focused on Bratislava and East Slovakia). This kind of analysis is done for each Member State and for each market.

Contribution to science and policy, and practical implications

The results of the project had a valuable scientific impact, with several high impact publications in journals in the Nature group and leading innovation journals (e.g. *Research Policy*).

[18] https://iri.jrc.ec.europa.eu/complexity/main-outputs/infographics

These results were also shared with policymakers and other (private and public) stakeholders in several occasions. The main event was a workshop on ‘Economic complexity to inform policy: From industrial innovation to industrial competitiveness’, held in June 2020[19]. We also had a presence at the European Week of Regions and Cities 2020[20] and at INOFEST 2020 in Bratislava[21], where we presented our results about their countries to Italian and Slovakian stakeholders, respectively.

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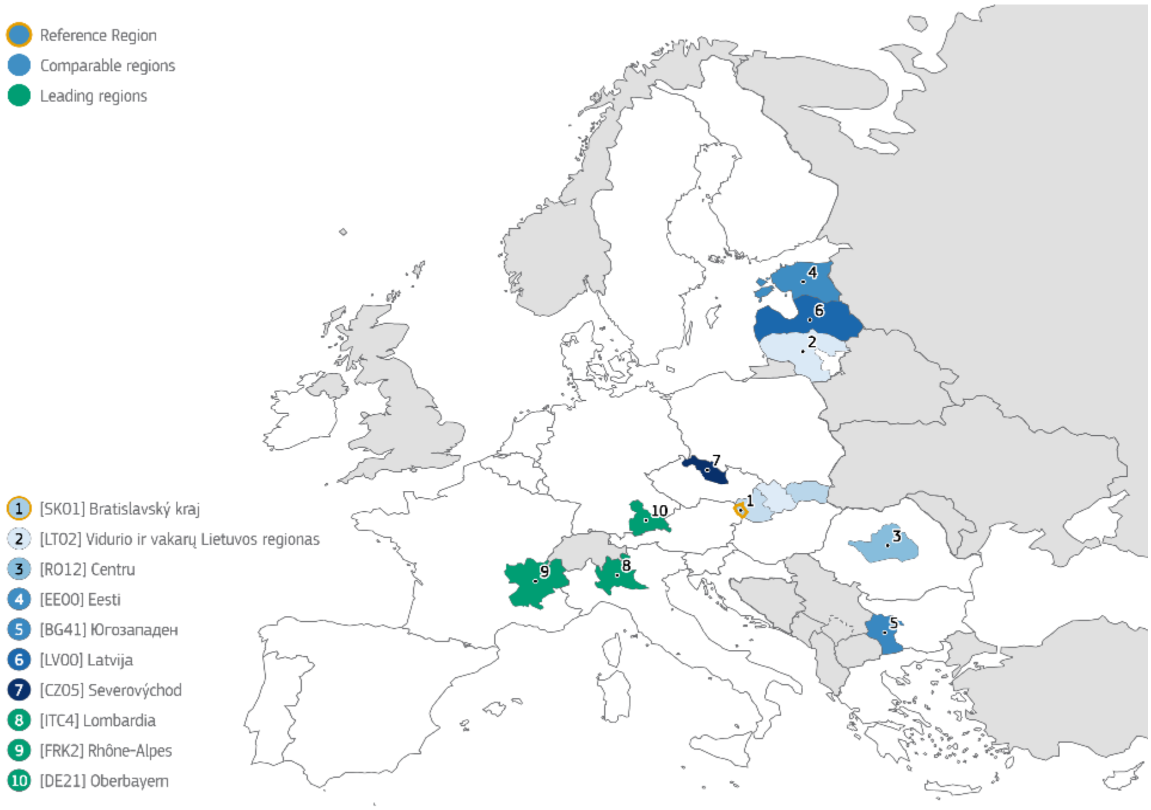


Figure 5.3. Regional capabilities of the innovation system of Slovakian regions specific to the export of “railway cars, closed and covered”, a product deemed a potential opportunity for Slovakia by the analysis. Comparison with regional competitors and EU market leaders. Source: https://ec.europa.eu/jrc/sites/jrcsh/files/jrc122086.pdf

5.3 Limitations, follow-up and further collaborations

Our work has been very well received by very different clients, and it is adapting accordingly, to deal with the needs of different clients. First of all, we are working to better integrate our workflow with the fourth-generation regional innovation strategy for smart specialisation (RIS4), to make economic complexity analysis work both as a quantitative foundation for the RIS4 platform and as a quantitative testbed of its efficacy. Second, we are collaborating with DG Economic and Financial Affairs to see how our work can be used to inform cohesion policy at the country level. In this respect we are also working to develop a standardised routine to help policymakers to read our analyses and make a diagnosis of the numbers provided. Finally, we are starting a collaboration with the International Finance Corporation – World Bank Group to work on the role of academic excellence in economic activities, a part of the innovation system that is not very well studied yet, and to write a handbook of best practices for economic complexity to inform policy.

Internally, (a) we are adding new layers to our analysis, in particular looking at the role of innovative start-ups in the innovation system, (b) we are developing our data structure to address more refined geographical

[19] https://iri.jrc.ec.europa.eu/complexity/main-outputs/workshops

[20] https://europa.eu/regions-and-cities/programme/sessions/1417_en

[21] https://inovato.sk/inofest/

scales, (c) we are working to have a more automatised process to deal with more requests from policy stakeholders and (d) we are developing new techniques to answer different questions.

We are looking to more external collaborations. On one side, we aim to strengthen our links with the World Bank Group and United Nations to define common best practices in using these techniques. On the other side, we are looking at new collaborations with leading academic institutions in the field, in particular the Sant'Anna School for Advanced Studies and the Enrico Fermi Centre for Study and Research in Rome, to further incorporate the latest advances of cutting-edge academic research. Finally, inside the European Commission we are looking at the integration of data sources within Unit B3, with other JRC Units (B6, C7) and with another DG (Research and Innovation), to further avoid duplicated efforts.

Bibliography

Dosi, G., Mathew, N., and Pugliese, E. (2020), 'What a firm produces matters: Diversification, coherence and performance of Indian manufacturing', *Research Policy 104152 (on line), ISSN 0048-7333*.

Pugliese, E. and Tacchella, A., (2020), 'Economic complexity for competitiveness and innovation: A novel bottom-up strategy linking global and regional capacities', INNO4GD Brief Series, Seville, European Commission.

Pugliese, E. and Tübke, A. (2019), 'Economic complexity to address current challenges in innovation systems: A novel empirical strategy linked to the territorial dimension', Technology and Innovation Challenges 2030 Brief Series, Seville, European Commission.

Pugliese, E., Cimini, G., Patelli, A., Zaccaria, A., Pietronero, L. and Gabrielli, A. (2019), 'Unfolding the innovation system for the development of countries: Coevolution of science, technology and production', *Scientific Reports*, Vol. 9, 16440.

Tacchella, A., Cristelli, M., Caldarelli, G., Gabrielli, A. and Pietronero, L. (2012), 'A new metrics for countries' fitness and products' complexity', *Scientific Reports*, Vol. 2, 723

Tacchella, A., Mazzilli, D. and Pietronero, L. (2018), 'A dynamical systems approach to gross domestic product forecasting', *Nature Physics*, Vol. 14, pp. 861–865.

6. Productivity transmission through value chains and the high-technology sectors

6.1 Participants and collaborations

The main authors of this work were David Martínez Turégano, Robert Marschinski (JRC Unit .B.5)

6.2 Activity

Current understanding and research question

Among other benefits, innovation helps to spur productivity. Inspired by the ideas developed by Timmer (2017), in this research we propose a measure of global value chain – total factor productivity (GVC-TFP), and a decomposition of its change over time into three informative factors: (a) changes in factor requirements (FRQ) associated with efficiency gains/losses in the use of capital and labour, (b) shifts in the distribution of value added due to changes in factor shares (FSH) and (c) shifts in the value chain composition (VCC), which are mainly due to geographical relocation of production stages.

Methodology / data used

The analytical work is based on the World Input–Output Database (WIOD)[22]. We use this methodology to analyse the evolution of GVC-TFP in different sectors between 2000 and 2014 across what are now the EU-27, comparing the periods before and after the Great Recession.

Findings

The traditional approach to measuring total factor productivity (TFP) evaluates the efficiency of the production process for a particular sector, combining labour and capital factors, as well as material and service inputs (such as the methodology developed in the EU level analysis of capital (K), labour (L), energy (E), materials (M) and service (S) inputs (EU KLEMS) and described by Stehrer *et al.*, 2019). These inputs are themselves the result of the combination of factors and inputs in previous production stages (upstream activities), so they introduce a certain degree of efficiency to the sectors where they are used (downstream activities).

Following a broad definition, the bundle of upstream and downstream activities that are necessary worldwide to put together a certain product is called a global value chain (GVC). Since the value added generated in each of the activities in a GVC is eventually distributed to the owners of labour and capital factors, we can think of a GVC as the outcome of international, regional and national fragmentation of production into labour and capital units distributed around the world (Timmer, 2017). Accordingly, the combined efficiency of use of these labour and capital units in different sectors and countries makes up the overall level of efficiency of a GVC, which we call the GVC-TFP.

A positive (negative) change in GVC-TFP in a particular country–sector pair describes an overall efficiency net gain (loss) along the full value chain up to the production stage in which the country–sector pair participates. Changes in GVC-TFP can be decomposed into the individual or aggregate contributions of the different participating production units (e.g. the contribution of business services to the change in overall efficiency in manufacturing value chains).

Furthermore, we propose a decomposition of these contributions into informative drivers explaining changes in GVC-TFP (see Box 6.1 for details): changes in FRQ associated with efficiency gains/losses in the use of capital and labour, shifts in the distribution of value added due to changes in the FSH over output and shifts due to changes in the VCC, which mainly correspond to the geographical relocation of production stages.

Based on this framework and the 2016 release of WIOD, we assess the performance of GVC-TFP across the EU-27 between 2000 and 2014, at both aggregate and sectoral levels, with particular focus on the role of efficiency gains in upstream value chain stages and structural shifts in the composition of value chains. The

[22] http://www.wiod.org/home

results of our analysis show a sharp contrast between the intensity, composition and driving forces of GVC-TFP developments before and after the Great Recession.

In the first subperiod (2000–2007), we observe a generalised growth in productivity, although the increase in GVC-TFP across countries showed a high degree of heterogeneity, with Member States that joined the EU in or after 2004 (EU-13) overperforming relative to the EU-15* (EU-15 excluding the United Kingdom) (Figure 6.1). Structural transformation and technological convergence in the EU-13 supported generalised efficiency gains across sectors that were transmitted to the whole economy through domestic supply chains (around a third of the domestic contribution corresponds to other sectors than the producing one).

On the other hand, the positive contribution of imported efficiency gains (i.e. a reduction in FRQ in foreign input suppliers) was also larger on average for the EU-13, benefiting from both a higher degree of trade openness and a higher share of manufacturing activities. For both groups of countries, the largest contribution of imported efficiency gains was from non-EU suppliers (60 % on average), particularly reflecting the catching-up process of China and other Asian developing countries.

Finally, the net effect of shifts in the composition of value added on changes in GVC-TFP was particularly negative for the EU-15*, as a result of less-efficient production units increasing their relative participation along value chains. This was the result of an increasing fragmentation of production processes, reflected in lower retention of value added per unit of output (negative contribution of the FSH component), and its international nature, captured by the geographical relocation of production to less-developed countries (negative contribution of the VCC component).

On a sectoral basis (Figure 6.2), TFP increased at a higher rate in manufacturing value chains for most countries in this subperiod, benefiting from the relocation of upstream supply stages to production units that showed a significant reduction in FRQ. The degree of (international) fragmentation in production processes, which was already higher for manufacturing than other activities, further increased during this subperiod.

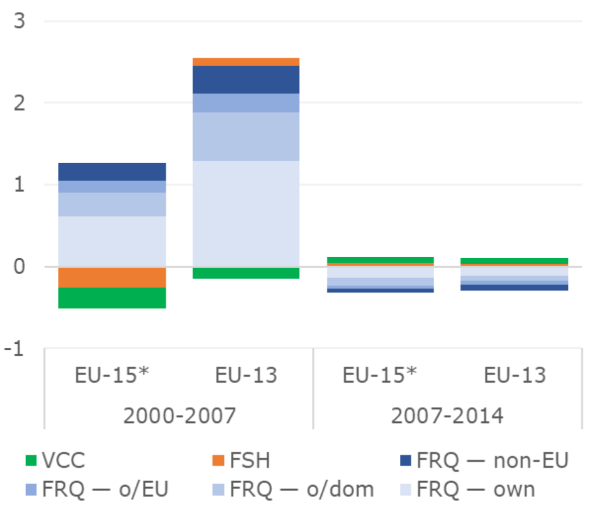


Figure 6.1. Contribution to GVC-TFP average annual change, by subperiod and group of countries (percentage points)

Notes: Average percentage points (p) of the calculated estimates will be 30 to 70 within each group of countries and subperiod; decomposition of the production-based GVC-TFP change into three factors: FRQ, FSH and VCC.

o/dom, other domestic sectors; o/EU, other EU countries; non-EU, non-EU countries.

Source: own elaboration based on WIOD.

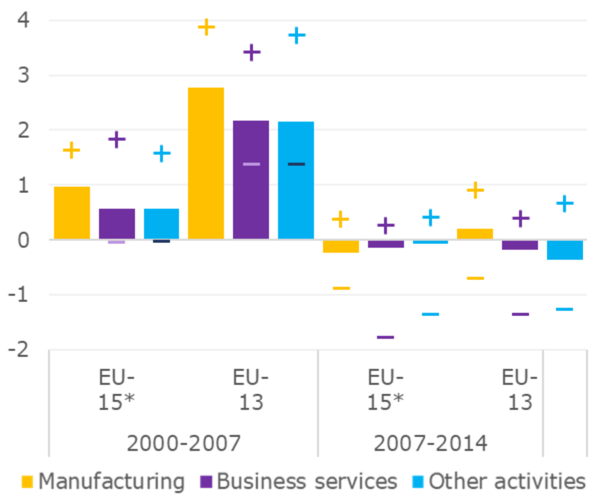


Figure 6.2. Sectoral GVC-TFP average annual change, by subperiod and group of countries (percent)

Notes: Within each group of countries and subperiod, the solid bar corresponds to the percent (p) of the calculated estimates equal to 30–70 average, the (+) to the p70–p100 average and the (–) to the p0–p30 average; sectoral production-based GVC-TFP.

Source: own elaboration based on WIOD.

However, a detailed analysis shows that, in some cases, the positive effect of higher efficiency gains in new production units was substantially (or fully) counteracted by the negative difference relative to previous efficiency levels (as illustrated by the example in Box 6.2); in other cases, efficiency gains in upstream activities, although probably contributing to improved profitability, did not translate into TFP gains for downstream producers. These developments also took place in non-manufacturing activities, but they were less intense and showed, particularly in the case of business services, a closer relation between TFP gains from the supply chain and own TFP gains.

The second subperiod (2007–2014) presents a clear contrast with the first one in a number of aspects. First, GVC-TFP gains turned out to be the exception instead of the norm, owing to the stop, and even reversal, of efficiency gains from FRQ, including, in a context of a global productivity slowdown (Eichengreen et al., 2017), producers in non-EU economies (Figure 6.1). Second, on a sectoral basis, developments in non-manufacturing activities explained a larger share of the dispersion of productivity performance across countries (Figure 6.2); some Member States even recorded significant drops in TFP in business services, which eventually had a negative effect on the efficiency of downstream activities through value chains, including exports of manufactures. Third, the shift of value-added distribution went in most cases in the opposite direction after the Great Recession, increasing the share of those production units that are more efficient (i.e. with lower FRQ), reflecting both the halt of international fragmentation (Timmer et al., 2016) and reshoring decisions (Eurofound, 2016).

Summarising these findings, we find a sharp contrast between the intensity, the sectoral composition, the geographical contributions and the nature of the driving forces of GVC-TFP developments.

Contribution to science and policy, and practical implications

In policy terms, our analysis provides an insightful approach to how productivity developments are transmitted from upstream to downstream activities, and to the factors driving changes of overall efficiency in value chains (i.e. changes in FRQ and shifts in the composition of value added). In the context of the economic crisis following the COVID-19 pandemic, import dependency and supply security loom large in the debate on the future of global trade, adding to pre-existing factors transforming GVCs (Unctad, 2020). It might be the case that production networks turn less global and hence productivity dynamics within the EU single market become more critical. In principle, a potential reshoring of production capacities could exert positive effects on EU productivity, directly due to the relocation of resources to more efficient production units than those of foreign suppliers and a higher share of tradable activities in the total economy, and indirectly by improving the resilience of EU value chains and lowering vulnerabilities to global shocks.

However, this poses important challenges in the light of the significant loss of EU competitiveness against manufacturing global competitors since 2000, including both downstream and upstream activities and those with high-tech content (Marschinski and Martínez-Turégano, 2019, 2020a,b; Martinez-Turégano, 2021). This has been particularly the case with electronics, in which the EU's global share has fallen even more than in total manufacturing, without evidence that specialisation in other segments of this value chain – such as scientific R & D, software development or IT services – could significantly mitigate the trend. On top of that, were the relocation eventually to take the place, a sustained path of productivity gains would be still needed. Beyond mere one-off effects of reshoring production to more efficient production units, this would require persistent innovation activities (R & D) as a systematic driver of such gains. In this sense, the EU single market would indeed benefit from a push to competition and efficiency in business services, which would spread to the rest of the economy through value chains, and the building of capacities and innovation in critical activities for overall productivity growth, such as electronic hardware, robotics, digitalisation and software development.

6.3 Limitations, follow-up and further collaborations

Our methodology could contribute to a comprehensive assessment of a strategic restructuring of EU value chains. However, on the data side, a number of caveats remain to be resolved in future research and call for careful interpretation of the quantitative results.

DG Economic and Financial Affairs has expressed interest in this research and the results.

Box 6.1. Factors explaining productivity changes through value chains

First, a change in the capital or labour needed for the same amount of output (what we call FRQ) corresponds to a shift in the efficiency level for a particular country–sector pair and is commonly associated with technological progress. The impact of these efficiency changes on the overall GVC-TFP depends on the degree of participation of this activity in the value chain, defined in terms of the share of value added (e.g. a reduction of 10 % in FRQ in business services accounting for 10 % of value added in manufacturing value chains would show a positive contribution of 1 percentage point in overall efficiency for manufacturing value chains).

Second, a change in the composition of the value added generated along a value chain also has an important effect on GVC-TFP changes due to production units showing different levels of efficiency in the use of labour and capital factors. If a certain share of the value added in a value chain moves to a production unit with lower (higher) FRQ per unit of output, this will generate a positive (negative) impact on the overall efficiency.

In our framework, a change in the composition of the value added has two possible sources. On the one hand, capital and/or labour units required for a certain activity can change the fraction of the value added that they retain relative to the amount of output (what we call FSH). This could be for a number of reasons, including the fragmentation of the production process (outsourcing, offshoring), as well as changes in relative prices of outputs and inputs, mark-ups, education and capital returns, workers' bargaining power, etc. On the other hand, keeping the FSH constant, the participation in value added could change as a result of a shift in the composition of value chains, i.e. a change in the country–sector pair as producing unit at a particular stage. Most of the shifts correspond to the geographical level, consisting of a sector in a country increasing its participation in a value chain to the detriment of the same sector in a different country. These changes are the result of competitive forces at some stage in a GVC, but associated shifts in upstream activities could be just reflecting the prevalence of regional or domestic networks (e.g. if a producer of machinery changes its main supplier of components to a different continent it is likely that services used by the component producer are also to a large extent displaced to the new location). On the sectoral level, technological developments or outsourcing could also generate major shifts in the composition of value chains, as shown for the case of electronics by Marschinski and Martínez-Turégano (2020a,b).

Box 6.2. A country–sector example: The French motor vehicle value chain

We look at a specific value chain to better illustrate how the different factors affect the development of GVC-TFP. For three different years, Table 6.1 provides the value chain characterisation for the manufacturing sector 'C29 – Motor Vehicles' in France in two dimensions that are used for the decomposition explained in Box 6.1.

On the left-hand side, we have the structure of value added by origin (adding up to 100 %), which corresponds to the weights used to compute the contribution of changes in FRQ within the different production units of the value chain. First, we observe a significant share of value added generated by French business services (over 20 %) and foreign input suppliers (around 40 %), higher in both cases than the share of the motor vehicle industry itself. Second, the overall share of French value added has declined over time, particularly to the benefit of countries outside Europe in absolute terms and EU-13 Member States in relative terms.On the right-hand side of the table, we have the average relative level of FRQ, which are used to compute the contribution of changes in value added shares. First, for those sectors involved in this specific value chain, we observe that the efficiency in the use of labour and capital is higher in France (FRQ per unit of output are less than half of the world average), particularly compared with EU-13 and non-European producers. Second, the relative FRQ in non-manufacturing domestic and EU-13 input suppliers have declined over time, becoming more efficient production units with respect to worldwide sectoral peers.

Table 6.1. Characterization of the French C29 – Motor Vehicles value chain by origin of value added

Origin of value added		Value added share (%) 2000	2007	2014	Relative factor requirements (%) 2000	2007	2014
France	Motor vehicles	21	18	19	46	47	49
	Other manufacturing	13	10	9	44	47	46
	Business services	27	29	24	58	57	45
	Other activities	4	4	4	43	41	35
Other EU	EU-15*	20	20	21	54	55	54
	EU-13	1	2	3	116	99	85
Non-EU	Europe	5	5	5	64	64	64
	Non-Europe	10	11	14	82	89	89

Notes: Value added share in one unit of output of French C29 – Motor Vehicles and relative FRQ based on sectoral differences from the world average.

EU15* = EU15 excluding the UK and France; EU13 = Member States from 2004 onwards; Non-EU Europe = Norway, Russia, Switzerland, Turkey, the United Kingdom; Non-Europe = rest of the world.

Source: own elaboration based on WIOD.

Now we look into the development of overall efficiency of the French motor vehicle value chain as measured by changes in its GVC-TFP. Table 6.2 summarises the estimation and decomposition for the two subperiods analysed in the main text, with particular detail on the contribution of changes in FRQ by origin of value added (same countries and sectors as in Table 6.1).

First, we observe that overall efficiency has hardly increased along this specific value chain in either subperiod (0.5 % or less per year). Second, whereas FRQ decreased in all cases in the first subperiod (more in EU-13 and non-EU input suppliers), positively contributing to GVC-TFP growth (percentage changes in FRQ are weighted by the corresponding value added share), the opposite happened in the second subperiod, with the exception of EU-13 participants. Third, in the first subperiod, the change in input suppliers to the benefit of less efficient production units (mainly located in EU-13 and non-European countries) resulted in a significant negative contribution to GVC-TFP (– 0.7 percentage points VCC), which counteracted to a great extent gains obtained from the aforementioned reduction in FRQ (+ 1.3 percentage points for aggregate FRQ); in contrast, changes in the composition of value added went in the opposite direction in the second subperiod, with more efficient production units increasing their participation in the value chain as a result of both higher retention of value added per unit of output and shifts in the structure of the value chain (+ 0.3 percentage points FSH and VCC).

Table 6.2. Decomposition of changes in GVC-TFP for the French C29 – Motor Vehicles value chain, by subperiod and contributing factor

		2000—2007		2007—2014	
GVC-TFP average annual change (i+ii+iii)		**0.5**		**0.1**	
i. FRQ					
	Origin of value added	*Change (%)*	*Contribution (percentage points)*	*Change (%)*	*Contribution (percentage points)*
France	Motor vehicles	-0.3	0.1	0.9	-0.2
	Other manufacturing	-1.6	0.2	0.5	0.0
	Business services	-0.4	0.1	0.0	0.0
	Other activities	-1.6	0.1	0.7	0.0
Other EU	EU-15*	-2.0	0.4	0.7	-0.1
	EU-13	-4.6	0.1	-0.8	0.0
Non-EU	Europe	-2.6	0.1	0.7	0.0
	Non-Europe	-2.4	0.2	0.1	0.0
Value added composition (net contributions in percentage points)					
ii. FSH		-0.1		0.3	
iii. VCC		-0.7		0.3	

Notes: EU15* = EU15 excluding the UK and France; EU13 = Member States from 2004 onwards; non-EU Europe = Norway, Russia, Switzerland, Turkey, the United Kingdom; non-Europe = rest of the world.

Source: own elaboration based on WIOD.

References

Eichengreen, B., Park, D. and Shin, K. (2017), 'The global productivity slump: common and country-specific factors', *Asian Economic Papers*, Vol. 16, No 3, pp. 1–41.

Eurofound (2016), 'ERM Annual Report 2016: Globalisation slowdown? Recent evidence of offshoring and reshoring in Europe', Luxembourg, Publications Office.

Martinez-Turégano, D. (2021).'The transmission of productivity through global value chains: formal concept and application to recent developments in the EU27'. JRC Technical Report No. JRC122076. Joint Research Centre.

Marschinski, R. and Martínez-Turégano, D. (2019), 'Reassessing the decline of EU manufacturing: A global value chain analysis', JRC Technical Report, EUR 29999 EN.

Marschinski, R. and Martínez-Turégano, D. (2020a), 'The EU's shrinking share in global manufacturing: A value chain decomposition analysis', *National Institute Economic Review*, Vol. 252, pp. R19–R32.

Marschinski, R., and Martínez-Turégano, D. (2020b), 'Electronics lead concerns over the EU's declining share in global manufacturing value chains', *VoxEU* (https://voxeu.org/article/eu-s-declining-share-global-manufacturing-value-chains).

Stehrer, R., Bykova, A., Jäger, K., Reiter, O. and Schwarzhappel, M. (2019), 'Industry level growth and productivity data with special focus on intangible assets', Vienna Institute for International Economic Studies statistical report.

Timmer, M. (2017), 'Productivity measurement in global value chains', *International Productivity Monitor*, Vol. 33, pp. 182–193.

Timmer, M., Los, B., Stehrer, R. and de Vries, G. (2016), 'An anatomy of the global trade slowdown based on the WIOD 2016 release', *GGDC Research Memorandums*, No GD-162, Groningen Growth and Development Centre, University of Groningen.

Unctad (2020), 'World Investment Report 2020: International production beyond the pandemic', United Nations.

7. Public grants and venture capital investments[23]

7.1 Participants and collaborations

Andrea Bellucci, Gianluca Gucciardi (JRC Unit B.1) and Daniel Nepelski (JRC Unit B.6) were the authors of this work.

7.2 Activity

Current understanding and research questions

This chapter compares public and private funding of innovative companies in Europe. In particular, it analyses different types of public grants and VC investments, looking at their relative contributions to firms' funding and investigating the characteristics of the target firms.

The objective of this analysis is twofold. Leveraging on a data set including information on both private VC investments and public grants (including the European Commission SME instrument), this work (a) investigates the evolution of public grants in terms of volume and number of transactions in the EU and (b) analyses the characteristics of firms that have received both VC and public grants in order to investigate the investment strategies of public and private entities.

Methodology / data used

This analysis is based on a data set matching information related to VC investments and public grants from VentureSource (Dow Jones), integrated with information related to funds granted by the European Commission within the SME instrument (Phase 1 and Phase 2) programme scheme between 2014 and 2017. The full data set includes 3 659 public grants, 77 % from the SME instrument programme and the remaining 23 % from other public funding organisations. A subset of the data set ('matched data set') obtained by matching the full one with Orbis (Bureau van Dijk) to get information on target firms includes a total of 696 grants, of which approximately 18 % are attributed to the SME instrument and the rest to other forms of public grants.

Findings

The main findings from the investigations are reported in Box 2. See Bellucci, Gucciardi and Nepelski (2021) for further details.

Box 7.1. Key takeaways

Key takeaways	- Since its introduction, the Horizon 2020 SME instrument has become an important source of public funding for SMEs, contributing 50 % of the total amount of public grants in 2017. - Almost two thirds of firms receiving public grants have also been targets of private VC investments. - Strong qualitative differences emerge between firms that receive private and public financing for instance with respect to their size and age at the date of the funding.

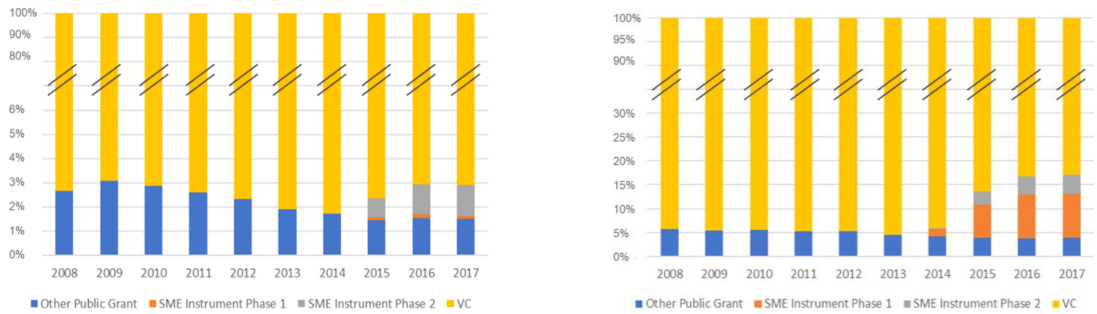
[23] This short chapter is an excerpt from a more comprehensive report by Bellucci, Gucciardi and Nepelski (2021). Andrea Bellucci (JRC Unit B.1), Gianluca Gucciardi (JRC Unit B.1) and Daniel Nepelski (JRC Unit B.6) jointly contributed to the production of that document and of this chapter.

The evolution of public grants and venture capital in the European Union

This section presents cumulative volumes and numbers of transactions, including SME instrument grants, other public grants and VC investments, in the period between 2008 and 2017. Concerning the total volume of funding, in 2008, European companies received EUR 4.3 billion. Within a decade, this amount quadrupled and reached EUR 20.5 billion in 2017. The change in percentage contributions of VC and public grants is presented in Figure 7.1.

Figure 7.1. Cumulative volumes by type (SME instrument, other public grants and VC)

% volumes (left) and % number of deals (right), 2008–2017



Source: JRC elaborations on VentureSource full database and SME instrument official data set.

In 2008, VC investments accounted for 97 % of the total cumulative volumes of funding. The remaining 3 % was provided by public entities in the form of public grants. In 2017, the contribution of VC investments remained stable. The SME instrument was introduced in 2014 and, since then, its role as a source of public funding for innovative companies has been increasing. In 2014, the SME instrument accounted for 0.03 % of the total funding and rapidly reached nearly 1.5 % of the cumulative volume of funding to innovative firms in Europe. In 2017, among the SME instrument phases, Phase 2 accounted for 92 % of about EUR 304 million, or EUR 280 million. Since the introduction of the SME instrument, the role of other public grants has decreased. Whereas in 2008 other public grants accounted for 3 % of the total funding to innovative companies, including VC, in 2017 their share decreased to 1.5 %.

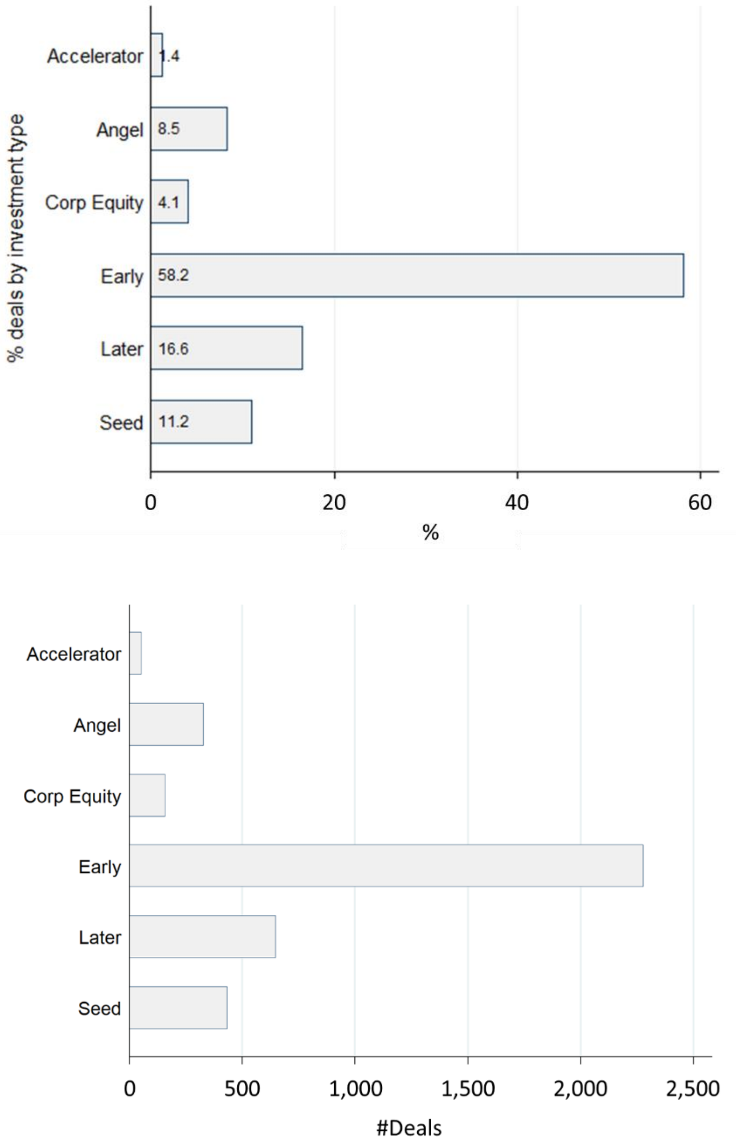
Regarding the total number of deals, i.e. including public grants and VC investments, in 2008 public entities and venture capitalists provided funding to innovative companies in Europe about 1 400 times. Like the volume of investments, this number more than tripled within a decade and reached about 4 900 in 2017. At the beginning of the period analysed, public grants accounted for 6 % and VC investments for 94 % of the overall number of deals. In 2017, the share of public grants in the number of deals increased to 17 %. In 2017, the number of SME instrument grants accounted for 77 % of all public grants and 14 % of the total number of deals, i.e. including public grants and VC investments. Because of relatively smaller grants, SME instrument Phase 1 accounted for over 70 % of the cumulative SME instrument grants in 2017.

The above analysis shows that the **share of public grants** in the cumulative volume of funding was substantially **stable between 2008 and 2017**, with a **shift of investments from other public grants to the SME instrument**. Within a very short period since its inception, the SME instrument became an **important source of funding in Europe**. In 2017, SME instrument grants accounted for 1.5 % of the cumulative volume of funding and 13 % of the total number of investments in innovative firms by private and public entities.

Public grants and venture capital funding

This section compares public grants with private VC investments. According to the information included in the matched dataset, 65 % of all firms receiving public grants were able to raise both grants from public entities and private VC investments, while the remainder received public grants only. This shows that **EU companies** that seek external funding will frequently **make use of both public and private sources of financing**. Figure 7.2 shows the types of VC funding raised by firms that also received public grants.

Figure 7.2. Percentage and number of VC deals (by category) raised by firms that also received public grants, % (top) and number of deals (bottom), cumulative 2008–2017.



Source: JRC elaborations on VentureSource-Orbis matched database and SME Instrument official dataset

Firms that received public grants between 2008 and 2017, received mainly early stages of VC funding, Firms that received public grants between 2008 and 2017 received mainly early-stage VC funding, accounting for 58 % of nearly 4 000 VC transactions. Later-stage VC represents the second largest type of funding by VC (17 %) for firms that also received public grant funding. Angel and seed funding represent 8 % and 11 % of all VC deals, respectively. Funding from accelerators and corporate equity firms constituted 1 % and 4 %, respectively, of all the private investments in firms that received public grants.

Features of firms receiving both public grants and venture capital investments

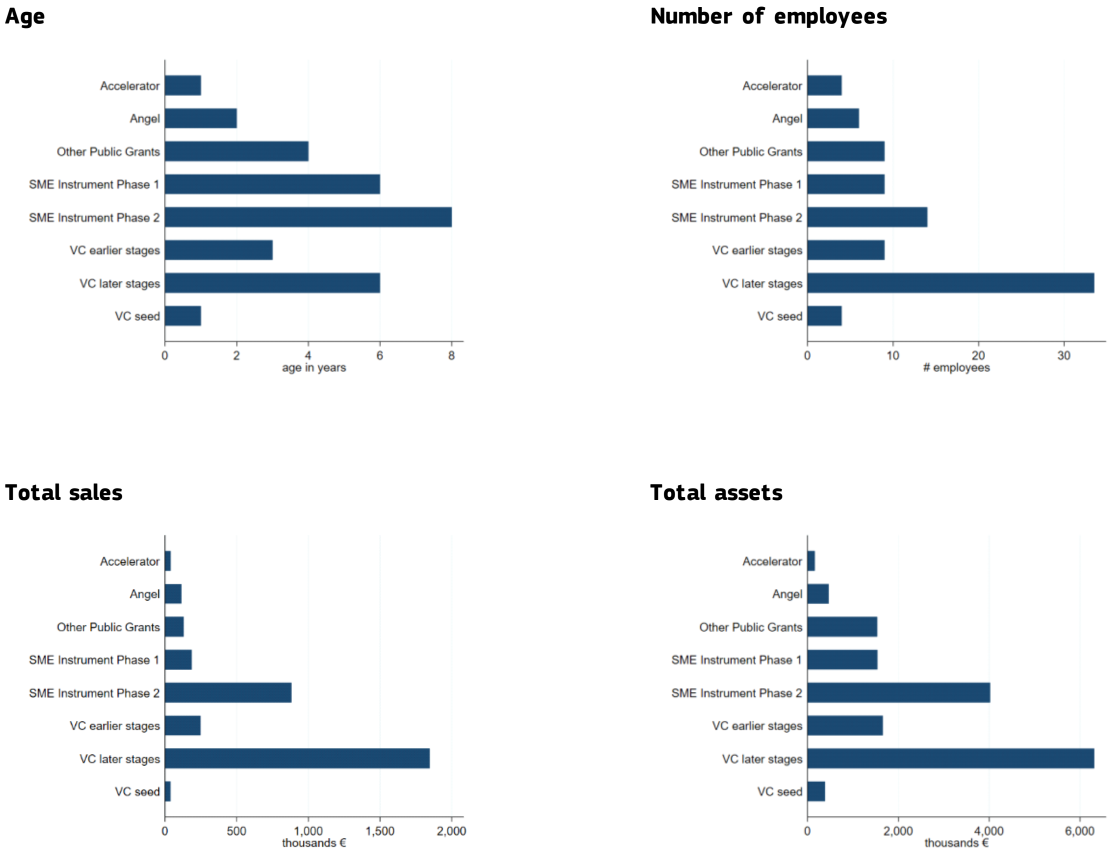
This last section analyses the investment strategies of public and private entities with respect to characteristics of firms that they target. In particular, it presents an overview of characteristics of firms when receiving public grants or VC investments by investment category and source, i.e. public and private.

According to Figure 7.3, firms receiving funding from accelerators are the youngest and smallest in terms of number of employees, total sales and assets. Regarding firms receiving funding from public entities other than the SME instrument, there are some remarkable differences between types of instruments. Public entities providing funding to innovative companies target relatively mature and large firms. On average, firms supported by the SME instrument are 6 years old in Phase 1 and 8 years old in Phase 2, and have nine employees. In terms of turnover, their median sales are at the level of EUR 0.19 million (Phase 1) and EUR 0.88 million (Phase 2). Their assets are worth EUR 1.5 million (Phase 1) and EUR 4 million (Phase 2).

Firms funded by the SME instrument Phase 1 resemble firms that receive early-stage VC. In terms of age, however, they are more similar to firms receiving later-stage VC funding. This indicates that firms supported by the SME instrument Phase 1 are small, with relatively high asset value, but with low levels of sales. Firms receiving SME instrument Phase 2 are the oldest, compared with firms targeted by other funding instruments. They have also considerably lower numbers of employees and total sales lower than firms receiving later-stage VC funding. This could indicate that the SME instrument beneficiaries are more mature and could have less growth potential than firms backed by VC.

Figure 7.3. Characteristics of firms when receiving public grants or private investments

Median, cumulative 2008–2017



Source: JRC elaborations on VentureSource-Orbis matched database and SME instrument official dataset

Contribution to science and policy, and practical implications

Summing up, the above findings indicate that **considerable differences** exist between the volumes and patterns of funding for innovative firms provided by **public** and **private entities**. The analysis also reveals that different types of funding entities target different types of firms.

This work may contribute to the scientific debate on the relationship between private investments and public grants. From a policy perspective, it could provide some insights into how public authorities and private investors cooperate on financing the start-up and launch of young SMEs in the EU.

7.3. Limitations, follow-up and further collaborations

The analysed sample could suffer from lack of representativeness, since some of the analyses were conducted on a subsample of firms for which financial and industrial information was available (the matched dataset). Further collaborations on the subject are possible within the JRC, the European Commission and beyond.

Reference

Bellucci, A., Gucciardi, G. and Nepelski, D., (2021), *Venture Capital in Europe – Evidence-based insights about venture capitalists and VC-backed firms*, EUR 30480 EN, Luxembourg, Publications Office, doi:10.2760/076298, JRC122885.

8. The role of venture capital in the financing of companies with high growth potential

8.1. Participants and collaborations

The work was led by JRC Unit B7, specifically by the High Growth Enterprises Team under the supervision of James Gavigan and Aurelien Genty. The work benefited from collaborations within Directorate B of the JRC, in particular with Andrea Bellucci and Gianluca Gucciardi (Unit B1), Daniel Nepelski (Unit B6) and Daniel Vértesy (Unit I.1), and with Pierfederico Asdrubali of DG Economic and Financial Affairs. The work also benefited greatly from feedback from Professor Colin Mason (University of Glasgow) and Professor Anita Quas (University of Milan 'La Statale').

8.2. Activity

Current understanding and research question

The purpose of the research is to explain how high growth enterprises raise finance throughout their entrepreneurial journey, and in particular if there are market inefficiencies in the access of firms to Venture Capital (VC) at their early stage.

Most governments have policies that aim to increase the supply of VC in support of high growth enterprises. The major focus of these interventions is on the start-up and early growth stages. However, the financing of high growth enterprises is rarely a "one shot deal". They are likely raising several funding rounds over time. In our research we found that VC is most active in ecosystems which contain a variety of source of finance, including grants, business angels, seed and start-up funds, and later stage funds. This highlights the need for research that adopts a longitudinal perspective on finance, looking at all the sources of finance that high growth enterprises have to raise for growing, including before a specific VC funding round and subsequently, and the inter-relationships between VC and these other sources of finance. One important point is to examine the subsequent financing of firms after their first VC investment to shed light on the extent to which firms that raise VC go to raise subsequent rounds of VC to scale-up. The identification of country, regional and sectoral differences is also an important dimension of our research.

Our work spans the fields of high growth entrepreneurship, innovation, and policy evaluation. We use mostly macro data in our projects to contribute to the European Semester related activities. Specific recent topics includes evaluation of research & innovation policy, and assessment of grant schemes such as the SME instrument.

Methodology / data used

These studies mainly refer to two analytical approaches: descriptive and econometric analysis. Our studies use primary data from three main database: Venture Source, Dealroom and Pitchbook. So far, our research has used extensively descriptive statistics, which are easy to read, and focussed on EU countries.

Our work, which is to a large extent data driven, is critically dependent on the underlying databases used and the definition of high growth enterprises that are applied.

Findings and implications for policy

A brief introduction to the findings and implications of the studies on VC and High Growth Enterprises (HGE) includes the following.

High growth enterprises: Demographics, finance and policy measures *(Flachenecker et al., 2019)*

In the financing section of the report, we focus on VC-backed companies. These are companies that with the injection of finance may achieve rapid and sustained growth. We use evidence from VentureSource to show how seed, start-up and later-stage investments vary across the EU. This implies that countries and regions need all three forms of finance for the emergence of high-growth firms. Seed and start-up VC will be ineffective if follow-on later-stage VC is not available. We also investigate the regional distribution of VC investment by stage. This is the first study of the geography of VC by stage. The main finding of this research is that Europe appears to have two types of regions. Regions such as Île-de-France have very developed early-stage (seed and start-up) and expansion-stage VC markets that meet the funding needs of start-ups and scale-ups. This contrasts with regions such as Apulia in Italy, where the supply of suitable investment opportunities for high-growth firms is restricted, so firms cannot grow quickly. This problem is particularly relevant to policymakers, as properly funded entrepreneurship could contribute to the economic development of lagging geographical areas and reduce cross-regional disparities. So far, we have used the findings from this research to inform our policy discussion with colleagues from DG Regional and Urban Policy.

Venture capital market in Europe *(Testa et al., forthcoming)*

In this research study, we first document the global state of VC. We then identify the clustering of VC-backed companies across EU countries and regions (NUTS 2). Using detailed postcode data on VC investment, we also cluster VC-backed companies across functional urban areas. We find that the geography of VC-backed companies remains extremely concentrated and unequal, with Berlin, London, Paris, and Stockholm accounting for roughly two thirds of all VC-backed investments across the EU. The original contribution of this work is to provide maps that help understand the geography of VC in Europe.. A very important finding – relevant to policy – is the uneven supply of capital across regions and consequently the economic disparity observed.

Financing companies with high growth potential: exploring the impact of COVID-19 on the venture capital in EU27 countries *(Testa, forthcoming)*

Given the importance of the entrepreneurial finance market for the economy, this study provides some timely insights into the uncertainty caused by the current crisis by using a novel source of real-time data provided by Dealroom. Our main research analyses the impact of COVID-19 on entrepreneurial finance by volume, type of funding stage and type of firm. We also examine the number of VC funds and amount of capital raised during the pandemic period. We use both annual and quarterly data to better contextualise these events within their prevailing circumstances and trends. The main finding emerging from our analysis is that the categories of finance most adversely affected are seed and early finance deals, which decreased by almost 40 % in the first three quarters of 2020 compared with those of 2019, whereas later-stage deals have shown much greater resilience. This shortage of finance for new start-ups is of crucial importance because research shows that start-ups born during recessions not only start smaller but also tend to stay smaller in the future even when macroeconomic conditions bounce back (Sedlacek and Sterk, 2017). The findings from this research can potentially be used to promote policy intervention in each EU country and inform the European Court of Auditors's activity report on VC.

In the future, more research will be needed to understand the role played by government VC (by size and stage of investment, sector and location) in the various VC market segments.

8.3. Limitations, follow-up and further collaborations

We will continue our collaborations with Professor Colin Mason and Professor Anita Quas to explore the impact of COVID-19 on business angels in Europe and the role of government VC in supporting companies with high growth potential, respectively.

We are exploring a potential collaboration with the European Investment Fund on the impact of COVID-19 on business angel investing in Europe.

We also hope to collaborate with Francesco Rentocchini and Lorenzo Napolitano (JRC B.3) on VC-related topics.

References

Flachenecker, F., Gavigan, J. P. Goenaga Beldarrain, X., Pasi, G., Preziosi, N., Stamenov, B. and Testa, G. (2019), 'High growth enterprises: Demographics, finance and policy measures', JRC Technical Report, EUR 30077 EN.

Sedláček, P., & Sterk, V. (2017). The growth potential of startups over the business cycle. *American Economic Review*, *107*(10), 3182-3210.

Testa, G. (forthcoming), *Financing companies with high growth potential: Exploring the impact of COVID-19 on the venture capital in EU27 countries.*

Testa, G. *et al.* (forthcoming), 'Venture capital market in Europe', Socio-economic regional microscope series.

9. Digital transformation and artificial intelligence

'Digital transformation' refers to the profound changes taking place in the economy and society because of the uptake and integration of digital technologies in every aspect of human life. The consequences of digital transformation will affect almost all EU policies. Hence, it is important and relevant for the JRC to observe current developments and their impacts, and explore future ones. In this context, artificial intelligence (AI) is recognised as one of the most important technologies increasingly transforming every aspect of society, and therefore deserves a particular focus within the broader digital transformation processes.

9.1 Participants and collaborations

Several work packages contribute to this general objective. **AI Watch**[24], led by Paul Desruelle, is the European Commission knowledge service to monitor the development, uptake and impact of AI for Europe. It is coordinated by JRC B.6. It has set up a large team to address the different tasks of the project, as well as collaborations with other units. In particular, it collaborates with Unit B4 on aspects related to education and AI. The Prospective Insights in ICT R & D (**PREDICT**)[25] project, managed by Giuditta de Prato, is based on a techno-economic segment analytical approach applied to AI and other dynamic technology-based industrial domains. The objective of the Support for Platforms and Data Economy (**SPADE**) project, coordinated by Néstor Duch-Brown, is twofold: first, to provide evidence and support for policy in the area of e-commerce and digital platforms; second, to understand the socioeconomic role and impact of data in the European economy.

European Location Interoperability Solutions for e-Government (**ELISE**) is a funded by the European Commission under the action 'Interoperability solutions for public administrations, businesses and citizens' (ISA^2) focusing on harnessing the use of spatial data and technology, and more generally on the role of location interoperability as a driver for enabling the digital government transformation. Its leader is Francesco Pignatelli. Monica Posada leads the 'application programming interfaces for digital government' and 'application programming interfaces strategy essentials for public sector innovation' work packages.

Within the JRC, Understanding the Impact of Artificial Intelligence on Human Behaviour (**Humaint**)[26] was a project of the Centre for Advanced Studies that started at the end of 2017, and in 2020 was transferred to Unit B6 'Digital Economy'. The project collaborates with Unit B4 on aspects related to AI and jobs. This project strongly interacts with the projects Cyber-Security, Privacy and Digital Identity, and Research for Security and Defence, and with relevant communities of practice.

9.2 Activity

Current understanding

The main objective of the activity is to enable the JRC to identify and address the current and future challenges for our economy and society resulting from the profound changes that are already taking place and will continue to take place at increasing pace, because of the uptake and integration of digital technologies in every aspect of human life.

AI has become an area of strategic importance with potential to be a key driver of economic development. AI also has a wide range of potential social implications. As part of its digital single market[27] strategy, the European Commission put forward in April 2018 a European strategy on AI in its communication 'Artificial intelligence for Europe' (European Commission, 2018a).

[24] *AI Watch* is the AI observatory, which aims to monitor the development, uptake and impact of AI for Europe. AI Watch is an initiative of the European Commission jointly developed by the JRC and the Directorate-General for Communications Networks, Content and Technology (DG CONNECT). More information can be found here: https://ec.europa.eu/knowledge4policy/ai-watch_en

[25] *PREDICT* analyses the supply of ICT, and the investments in R & D in ICT, in Europe, with comparisons with major competitors worldwide. PREDICT is a collaboration between the JRC and DG CONNECT.

[26] More information about HUMANIT can be found here: https://ec.europa.eu/jrc/communities/en/community/humaint

[27] More about the JRC work on the Economics of the Digital Single Market: https://ec.europa.eu/jrc/en/research-topic/digital-single-market

Subsequently, in December 2018, the European Commission published a 'Coordinated plan on artificial intelligence' (European Commission, 2018b), on the development of AI in the EU. The coordinated plan mentions the role of AI Watch in monitoring its implementation.

The JRC and the Directorate General for Communications Networks, Content and Technology (DG CNECT) have been working together on AI since December 2018, contributing to the development of the EU policy agenda on AI and monitoring of the implementation of the coordinated plan, notably in the context of the AI Watch project, a collaboration formalised with a 3-year administrative arrangement signed in December 2018. The project will also contribute to the periodic revisions of the coordinated plan (e.g. set out by the European Commission, 2020).

AI systems, when applied in practical applications, have an impact on human behaviour. On the one hand, AI provides cognitive assistance to humans, such as helping us to interpret data more efficiently and discover hidden knowledge in large data resources. On the other hand, these AI systems also affect human decision-making and cognitive tasks.

Dynamic and rapidly evolving technology-based domains are not reflected in available industrial classifications, and their structures, dynamics and underlying networks often escape mapping and analytical efforts. The unit has been working on the identification of these activities through the application of novel techniques.

Digital platforms are a new type of organisation that, by using data and algorithms, brings several types of users together and facilitates interactions between them, acting as an improved mechanism to address the fundamental problem of economic organisation: how to coordinate supply and demand when information is imperfect, to reach the highest possible efficiency. At the same time, these platforms raise concerns and are increasingly subject to scrutiny by regulators. How can economic efficiency gains and power concentration around very large digital platforms be combined with an equitable distribution of welfare in a data-driven economy?

Spatial data can provide valuable insights but these are not yet fully leveraged by public administrations, citizens and business. Hence, the ongoing digital transformation processes should consider 'rewiring' the data integration and business processes by harnessing the location dimension where possible to exploit greater knowledge.

One technical solution can be the generalisation of application programming interfaces (APIs), since they enable the integration of systems and actors in increasingly complex digital environments through their modularity: digital processes and data sets can be easily packaged into modules, which can be reused and recombined for different applications.

Research questions

The main research questions the project addresses are all related to the effects of the digital transformation in the economy and society. Some of the main research questions are as follows.

- How is the ecosystem of specific technology-based segments structured? How does it evolve and what are the underlying networks?
- What is the role of spatial data in digital transformation?
- How can location intelligence help in providing Europe-wide cross-border public services?

The related objectives are the following.

- To monitor the development, uptake and impact of AI in Europe, in order to support the implementation and further development of the European strategy for AI. This objective includes in particular helping DG Connect to monitor how Member States are implementing their commitments with respect to the coordinated plan on AI.
- To advance the scientific understanding of the impact that AI systems have on human behaviour.
- To assess which new technological and economic changes are likely to pop up in this fast-changing digital technology- and data-driven platform economy.
- To identify which public policy challenges are likely to emerge in the wake of this ever-advancing evolution.

- To identify API-related technical, organisational and legal essentials to unlock data-driven innovative potential in organisations.

Methodology / data used

The activity embraces a myriad of methodologies and techniques – both qualitative and quantitative – in order to achieve the abovementioned objectives and answer the research questions. Among the different methodologies used in the project, we can mention data analysis, web data scraping, machine learning, desk research, meetings and interaction with Member States, workshops with experts, stakeholder panels, pilot schemes, literature review, surveys, interviews and expert consultation.

In terms of data, some studies are based on micro-level data coming from several sources, others on web-scraped data or official statistics, surveys and questionnaires. Some work packages rely on subscriptions to relevant databases, while others tend to rely on openly available data.

Findings

The outcomes of the activity are multiple and cover a wide scope of activities, from publications to conferences. Some examples are listed below.

AI Watch monitors the EU's industrial, technological and research capacity in AI; AI-related policy initiatives in the Member States; uptake and technical developments of AI; and AI impact. AI Watch has a European focus within the global landscape. It has already delivered a number of key results and deliverables:

- a collection and analysis of national AI strategies in the EU Member States, in collaboration with the OECD and in direct interaction with Member States' representatives;
- a mapping and analysis of the worldwide AI ecosystem landscape (from research to industry).

AI Watch data collection and analyses are updated yearly (the first update is due by early 2021). In addition, AI Watch has also developed several methodology reports:

- a comprehensive methodology to estimate AI investments in Europe;
- a first report on the definition and taxonomy of AI;
- a methodology report on assessing the European robotics market;
- a roadmap report on producing an AI index.

In the case of Predict, the findings are specific to the segment/domain addressed. In particular, the approach is being applied to the mapping of the AI domain in the framework of the AI Watch exercise. This offers an overview of the worldwide competitive landscape and of the relative strengths in different thematic areas, analysis of the network of excellence in R & D, and more.

The work of SPADE has addressed several policy-relevant initiatives, such as geo-blocking, the data strategy and the platform-to-business regulations. Several reports have been published and, as a complementary activity, some scientific papers have been submitted to journals.

For ELISE, most of the outputs are made public to anyone through the ELISE JoinUp space[28]. In addition, ELISE proposes a rich agenda of events aiming to promote ELISE results as well new topics of research.

The adoption of APIs in organisations was observed to (a) act as a catalyst of the digital transformation process; (b) foster innovative processes with relatively low investment efforts; (c) produce efficiency gains; (d) enable digital interactions with internal and external actors.

Contribution to science and policy, and practical implications

From AI Watch in-depth analyses, we will be able to understand better the EU's areas of strength and areas where investment is needed. AI Watch will provide an independent assessment of the impacts and benefits of AI on growth, jobs, education and society.

HUMANIT has identified three main challenges and contributed to addressing them. First, it is difficult to access open and representative behavioural data needed to study human–AI interaction, especially in sensitive and complex scenarios. A second challenge is the definition of standard methodologies and

[28] *Joinup* is an e-platform created by the European Commission to provide a common venue that enables public administrations, businesses and citizens to share and reuse IT solutions and good practices, and facilitate communication and collaboration on IT projects across Europe. (more information can be found at https://joinup.ec.europa.eu/collection/joinup/about)

appropriate metrics for the evaluation of AI systems and for running user studies in human–AI interaction. A third is the need to carry out this research at the intersections of different disciplines, with diverse teams (e.g. in terms of gender or cultural background) and with AI system developers understanding the social context in which AI systems are embedded.

The work under PREDICT makes it possible to produce quantitative indicators to explore technology-driven segments of the economy not otherwise covered, and to explore the worldwide networks behind them with the aim of supporting the EU's strategic autonomy policy and, more generally, policies targeting the digital transformation.

The SPADE project has provided the first ever evidence on the roles of some digital platforms and the strategies they employ to leverage their dominant positions vis-à-vis their different groups of users. Similarly, it has provided sound and robust evidence to overcome the geo-blocking practices commonly employed by retailers, which undermine the digital single market. Finally, it has provided innovative analysis of the issues that hold back data sharing in the EU, while providing solid insights into the policies that would and would not work.

ELISE supports Better Regulation and digital single market strategy goals, including specific actions of the e-Government action plan[29] and the European interoperability framework[30], which are reinforced by the Tallinn Declaration[31] vision and the communications on Building the data economy[32] and on Artificial intelligence for Europe[33]. The ELISE action builds on the principles of the INSPIRE directive[34], which establishes an infrastructure for environmental spatial information in Europe.

The work of the API team has identified the important role that APIs play in organisations' digital innovation and how important is to get the API strategy right to ensure the efficiency, robustness and resilience of digital infrastructures. Organisations can use the framework of API adoption proposed by the JRC to identify actions to profit better from their API-enabled infrastructure.

9.3 Limitations, follow-up and further collaborations

The limitations faced by the activity are common to most research groups. The most important could be data availability, tight deadlines for contractual deliverables, resource scarcity, sudden changes in priorities and lack of relevant information from partner DGs, among others.

Given the importance of the new political priority based on 'A Europe fit for the digital age'[35], it is expected that most of the current activities will be continued. For the 2021–2022 work programme, these have been restructured into two project portfolios, one dealing with digital transformation and AI, and the other around data and platforms.

In the context of AI Watch, the JRC works in close contact with DG Connect, the Member States, the OECD AI Policy Observatory and other AI observatories in Europe, such as the German AI observatory launched in March 2020 by the German Federal Ministry of Labour and Social Affairs, and the AI observatory run by Politecnico de Milano.

Similarly, the HUMAINT team has established contacts with researchers from different institutions worldwide. Given that the project was in an exploratory phase, HUMAINT has not yet engaged in formal policy advice, but has contributed to several JRC flagship policy reports.

The SPADE project collaborates intensively with several DGs, in particular DG CONNECT, DG Internal Market, Industry, Entrepreneurship and SMEs, and DG Competition. In addition, several collaborations with academic institutions such as the Toulouse School of Economics Digital Centre and the MIT Initiative on the Digital Economy, as well with individual researchers, are ongoing.

In the case of ELISE, collaboration with DG Informatics and DG Connect should be further strengthened, as common research topics are likely to be explored. The relationship with the Member States should continue, but approaches to local governments, SMEs and associations closest to the provision of services should be prioritised too.

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[29] https://ec.europa.eu/digital-single-market/en/european-egovernment-action-plan-2016-2020

[30] https://ec.europa.eu/isa2/eif_en

[31] http://ec.europa.eu/newsroom/document.cfm?doc_id=47559

[32] https://eur-lex.europa.eu/content/news/building_EU_data_economy.html

[33] https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe

[34] http://inspire.ec.europa.eu/about-inspire/563

[35] https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age_en

Finally, the JRC B6 API team has developed a multi-layered community network of stakeholders with public (local, regional, national), private, academic and decision-making representatives. This community expands into different domains such as smart cities, public sector innovation and sectoral innovation (e.g. mobility and agriculture).

Bibliography

European Commission (2018a), Commission communication – 'Artificial intelligence for Europe' (COM(2018) 237).

European Commission (2018b), Commission communication – 'Coordinated plan on artificial intelligence' (COM(2018) 795).

European Commission (2020), 'White Paper on artificial intelligence' (COM(2020) 65 final).

10. Projecting opportunities for industrial transitions in lagging regions

10.1. Participants and collaborations

The Projecting Opportunities for Industrial Transitions (POINT) methodology has been jointly developed by JRC B.3 and several external experts, including academics and policy practitioners, as a core strand of the JRC Lagging Regions project [36], led by Mark Boden (JRC Unit B3). This particular activity is coordinated by Dimitrios Pontikakis, Anabela Marques Santos and Mark Boden (JRC Unit B.3), who perform conceptual, methodological and empirical work on industrial transitions under the Working Group on Understanding and Managing Industrial Transitions[37]. Dimitrios Pontikakis also leads the industrial transition reviews of Andalusia, Bulgaria and Greece. Marina Ranga (JRC B.3) leads the industrial transition review of Romania. Inmaculada Perianez Forte and Ramón Companó contribute to the review of Andalusia, Elisa Gerussi contributes to the review of Bulgaria and Jayne Woolford has sought to develop the interest in industrial transition among selected Polish regions (all JRC B.3). Another participating colleague in JRC B.3 is Pietro Moncada-Paternò-Castello, who is a member of the Working Group Advisory Board. The Working Group Advisory Board includes leading academic experts in their fields (system innovation, strategic niche management, innovation policy, foresight, participatory governance, regional science) and policy practitioners and analysts from the Generalitat de Catalunya, VINNOVA (the Swedish innovation agency), the Irish Department for Business and the OECD.

10.2 Activity

Current understanding

The notion of industrial transition was introduced in 2018 as one of the proposed fulfilment criteria for the conditionality of ‘good governance’ in the context of preparation for the next programming period of the European structural and investment funds (European Commission, 2018). The term was used in this policy context as a catch-all for employment-affecting structural change, for which authorities that administer structural funds would have to prepare and introduce mitigating actions. No formal definition, or framework for understanding these transitions and the role of policy, was offered. Indications at the time were that ongoing industrial transitions in Europe were exerting substantial pressures on employment, with entire industries and professions under threat in the following decade (for a sectoral dimension of transition challenges see, for example, OECD, 2018a, pp. 68–76; for professions at risk of automation see OECD, 2018b, pp. 45–53).

Research questions

In July 2019 the JRC launched a Working Group on Understanding and Managing Industrial Transitions. The questions the working group sought to answer were:

- how to understand the industrial transitions that are currently ongoing in Europe and its territories in ways that are useful for policy;
- how to manage industrial transitions in ways that maximise opportunities for high-quality employment creation.

After the launch of the European Green Deal, the activity became more focused on the twin green and digital transitions, and emphasised the identification of industrial development pathways that combine economic prosperity, with environmental sustainability and social cohesion.

Methodology / data used

POINT is a structured methodology for carrying out reviews of industrial transition from a system innovation (or transformative innovation) perspective. The POINT methodology was developed by the JRC and a number of external collaborators with relevant expertise and is documented in a recently published JRC report

[36] The project, conducted in cooperation with DG Regional and Urban Policy, aims to support the targeted Lagging Regions to implement a preparatory action of the European Parliament (see https://s3platform.jrc.ec.europa.eu/ris3-in-lagging-regions).

[37] https://s3platform.jrc.ec.europa.eu/industrial-transition

(Pontikakis *et al.*, 2020). It evolved in response to experience from the pilot reviews and was discussed extensively in the working group.

The POINT approach frames the transition problem at the level of the sociotechnical system, and recognises that, in addition to organisational-level innovation, the system itself must change, and seeks policy directions that can enable system-level innovation. The methodology guides experts through a series of questions. It includes suggestions for evidence-gathering approaches building on both desktop research and a large number of interviews with stakeholders in the territory (typically over 50). In each territory under review and for an industrial theme suggested by the authorities, the findings of the transition review are documented in a report that:

- provides evidence about the production and consumption system affected and its direction;
- identifies realistic transition pathways and associated institutional, investment and skills needs;
- proposes governance solutions so that disparate policy domains coordinate under a coherent industrial development logic;
- makes concrete policy recommendations for the advancement of the transition and for managing its downsides.

In addition to interviews, other sources of evidence used include science and technology innovation data, sectoral output and employment statistics, company databases (such as Orbis), and ad hoc indicators and other information relating to the global impulse driving the transition (e.g. information about digitalisation, energy and transport).

Findings

The key outcomes from this activity are the methodology for the reviews and, alongside it, a conceptual framework that combines insights from several converging strands of literature. In short, the POINT reviews are a tool to gather evidence, in a resource-efficient and timely manner, that contributes to holistic planning and enables coordination within governments and broad stakeholder mobilisation.

In terms of empirical findings from the reviews, the most noteworthy are the programming and planning gaps that we systematically observe across territories. The most glaring gap is arguably the absence of linkages between policies aimed at supporting consumer/household investments in sustainability (e.g. energy-efficient buildings, environmentally friendly transport) and policies in support of business investment. Arguably, this is but one symptom of the graver problem of the inability of governments to plan holistically and sequence their interventions. Possible governance mechanisms that could address this problem include mission-oriented strategies, roadmaps and shared agendas.

Contribution to science and policy, and practical implications

The activity's scientific contribution is twofold: (a) concepts and rationales for industrial transition, drawing from vanguard thinking in the diverse literatures of system innovation, new industrial policies, sustainability transition management and innovation governance; (b) methods for gathering appropriate evidence to inform policy, improved through experience with territorial reviews of industrial transition.

A key contribution of the reviews is a better understanding of the production and consumption systems undergoing rapid structural change. Evidence is currently lacking about the direction of long-term industrial change: systematically available evidence is, even in the best of cases, usually limited to sectoral output and employment statistics, attendant business support, and input or output indicators of corresponding science and technology systems, and occasionally extends to education and skills systems, all of which are undoubtedly important. Yet extensive and authoritative literature on historical techno-economic transitions emphasises the role of broader interplays. To mention just a few, these include interplays between:

- institutions, markets and technological trajectories (Dosi, 1982, 1988);
- the financial sector and business investment (Perez, 2002);
- public policies and investments in large physical infrastructures, and the development of vanguard production and innovation capabilities (Bell, 2009; Chang and Andreoni, 2020);
- identities, values and aspirations, and normative understandings of directions of social 'progress' (Geels, 2004; Stirling, 2009).

Evidence on the incidence of and potential for such system-level innovation, including changes in relationships, governance structures, coordination regimes and ways of mobilising resources, is generally unavailable. Identifying multicausality and systemic causes is only possible with a system-level examination. This can be effectively done, and in time to be of use to policy, with a review.

In terms of contribution to policy, the reviews of industrial transition are unique tools to gather evidence; identify directions for the transition that are a good match not only for the territory's material strengths but also for its values and aspirations; and help the competent authorities plan systemically. For example, a review can reveal opportunities for linking potentially synergetic production subsystems (e.g. energy and transport, or ICT services and manufacturing), reframe challenges and broaden policy options. Importantly, the reviews provide actionable recommendations to enable policymakers to act in the here and now, about issues that slowly but surely affect entire territories over long-term horizons and call for extensive coordination and mass mobilisation.

This activity, particularly the territorial reviews of industrial transition, has attracted advance recognition from policymakers. A high degree of interest and engagement by the Member State authorities has elevated the pilot reviews into politically important exercises, already feeding directly into ongoing policy drives, including the new energy strategy of Andalusia and its future smart specialisation strategy, the recovery and resilience plan and the just transition plan of Greece and post-2020 European structural and investment funds programming in Bulgaria.

10.3 Limitations, follow-up and further collaborations

As the activity started only in 2019 and with limited resources, the body of evidence collected so far rests on a limited set of pilot reviews (Andalusia, Bulgaria, Greece and Romania). In the future we will need to broaden experience to a greater variety of territories. In addition, the reviews done so far are confined to a group of low-income or low-growth territories, although the methodology may arguably have an even greater impact in middle-income territories. It will be important to couple the reviews with mechanisms for building support coalitions among stakeholders that can help realise desirable transition paths. These can build on the momentum of the reviews, and include JRC actions that actively support authorities in orchestrating forms of participatory governance that will be necessary to build broad support coalitions.

Moreover, it will be important to accompany the qualitative body of evidence of the reviews with quantitative empirical studies, notably on the determinants of employment shifts from less to more productive sectors, and employment shifts from more to less carbon-intensive sectors (Marques-Santos and Pontikakis, 2020). Finally, the understanding of possible transition pathways can be strengthened by formal quantitative modelling exercises, building on the rich modelling tradition of system dynamics (Forrester, 1961), to evaluate alternative future scenarios of disequilibrium processes that cannot be analysed using conventional economic models (e.g. outcomes driven by the coupling of hitherto separate production systems, which contribute to rapid diffusion, which is further accelerated by increasing returns to adoption).

Within the JRC, the POINT concepts and methodology are informing the evolution of future smart specialisation strategies for sustainability. There is significant interest in this work within the EU institutions, and there are even ongoing discussions about possible future collaborations with organisations beyond the EU as well.

References

Bell, M. (2009), 'Innovation capabilities and directions of development', *STEPS Working Paper*, No 33, Brighton, STEPS Centre (https://steps-centre.org/wp-content/uploads/bell-paper-33.pdf).

Chang, H. J. and Andreoni, A. (2020), 'Industrial policy in the 21st century', *Development and Change*, Vol. 51, No 2, pp. 324–351, doi:10.1111/dech.12570.

Dosi, G. (1982), 'Technological paradigms and technological trajectories: A suggested interpretation of the determinants and direction of technical change', *Research Policy*, Vol. 11, pp. 167–162.

Dosi, G. (1988), 'Sources, procedures, and microeconomic effects of innovation', *Journal of Economic Literature*, Vol. 26, pp. 1 120–1 171.

European Commission (2018), Proposal for a Regulation or the European Parliament and of the Council "laying down common provisions on the European Regional Development Fund, the European Social Fund Plus, the Cohesion Fund, and the European Maritime and Fisheries Fund and financial rules for those and for the Asylum and Migration Fund, the Internal Security Fund and the Border Management and Visa Instrument' - Annex IV, Document 2, p. 19 Strasbourg, 29.5.2018 COM(2018) 375 final (https://eur-lex.europa.eu/resource.html?uri=cellar:26b02a36-6376-11e8-ab9c-01aa75ed71a1.0003.02/DOC_3&format=PDF)

Forrester, J. W. (1961), *Industrial Dynamics*, MIT Press, Cambridge, MA.

Geels, F. W. (2004), 'From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory', *Research Policy*, Vol. 33, No 6–7, pp. 897–920.

Marques-Santos, A. and Pontikakis, D. (2020), 'Structural change and megatrends: How can European funds support regions in the transition?', ERSA Web Conference 2020, 25–27 August.

OECD (2018a), *Productivity and Jobs in a Globalised World: (How) can all regions benefit?*, Paris, OECD Publishing.

OECD (2018b), *Job Creation and Local Economic Development 2018: Preparing for the future of work*, Paris, OECD Publishing (https://doi.org/10.1787/9789264305342-en).

Perez, C. (2002), *Technological Revolutions and Financial Capital: The dynamics of bubbles and golden ages*, Cheltenham, Edward Elgar.

Pontikakis, D., Fernandez, T., Janssen, M., Guy, K., Marques Santos, A., Boden, M. and Moncada-Paternò-Castello, P. (2020), 'Projecting Opportunities for Industrial Transitions (POINT): Concepts, rationales and methodological guidelines for territorial reviews of industrial transition', JRC Scientific and Technical Report, JRC121439, EUR 30375 EN, Luxembourg, Publications Office of the European Union, doi:10.2760/590389 (https://s3platform.jrc.ec.europa.eu/documents/20182/392265/Projecting+Opportunities+for+INdustrial+Transitions+%28POINT%29+Concepts%2C+rationales+and+methodological+guidelines+for+territorial+reviews+of+industrial+transition/eecfbd60-d057-41d0-9c1e-a46772b1de28).

Stirling, A. (2009), 'Direction, distribution and diversity! Pluralising progress in innovation, sustainability and development', *STEPS Working Papers*, No 32, Brighton, STEPS Centre.

11. Industrial innovation for transformation

11.1 Participants and collaborations

The main participants to this activity were Sara Amoroso, Marta Dominguez, Nicola Grassano, Fernando Hervás, Pietro Moncada-Paternò-Castello, Lesley Potters, Emanuele Pugliese, Alessandro Rainoldi, Dimitris Pontikakis, Alexander Tübke, Antonio Vezzani (all from JRC Unit B.3) and Alessandra Collechia (Organisation for Economic Co-operation and Development – OECD), as members of the Steering Committee of the 7th European Conference on Corporate R & D and Innovation (CONCORDi 2019)[38].

Román Arjona (European Commission, DG Research and Innovation, Belgium) Anna Bergek (Chalmers University of Technology, Sweden), Alex Coad (Universidad Pontificia del Perù, Peru), Chiara Criscuolo (OECD, France), Koen Frenken (Utrecht University, Netherlands), Bronwyn H. Hall (University of California at Berkeley, United States), Pietro Moncada-Paternò-Castello (JRC B3, Spain), Irmgard Nübler (International Labour Organization, Switzerland), Raquel Ortega-Argilés (University of Birmingham, United Kingdom), Sven Schimpf (Fraunhofer, Germany), Mariagrazia Squicciarini (OECD, France), Reinhilde Veugelers (Katholieke Universiteit Leuven, Belgium) and Marco Vivarelli (Università Cattolica di Milano, Italy), as members of the Scientific Committee of CONCORDi 2019.

11.2 Activity

Current understanding and research question

As innovation continues to transform industries and society, there is renewed attention to industrial innovation policies. Key related aspects are already emphasised in the new political orientation of the European Commission's President, Ursula von der Leyen, in 'Political guidelines for the next European Commission 2019–2024'[39].

In order to discuss challenges related to the profound structural transformation due to technological, business and social innovation, and provide useful support to the EU's industrial R & I policy agenda, the JRC and the OECD co-organised CONCORDi 2019 on 25–27 September 2019. It focus was on 'Industrial innovation for transformation'. The results of this conference are the subject of this chapter.

Several challenges in the industrial transformations required were tackled in the conference. Central topics were the shifting technological landscape, misaligning of industrial profits, environmental sustainability and societal sustainability, in terms of both level of employment and its unequal distribution within and between regions. Particular attention was given to the complex interaction between these issues and the different aspects of the industrial innovation landscape.

The objectives of CONCORDi conference series are to harvest the frontier knowledge on economics of industrial innovation, set up a common agenda among scientific peers, which will hopefully support the present and future needs of EU policymakers, and help bridge the gap between academia and the policy sphere with constructive interaction.

Methodology / data used

This conference is positioned in the area of knowledge covering economics and industrial innovation policy. It is considered the reference on corporate R & D and innovation in the EU. It brings together new evidence from academia and research organisations, recent experiences of private economic players and up-to-date insights into EU policymaking. Research work presented at the conference is based mainly on quantitative information, and in particular on micro data.

At CONCORDi 2019, a total of 278 people came to the conference, with an average of more than 170 attendees a day. They came from 15 EU countries and from 18 non-EU countries, including, Brazil, Canada, Japan, Mexico and Morocco, Russia, South Korea, Switzerland Turkey, and the United States.

[38] https://iri.jrc.ec.europa.eu/concordi-2019

[39] Von der Leyen, U. (2019). Political guidelines for the next European Commission 2019-2024. European Commission, Brussels. PE, 658, 2020-54.

Out of 150 proposed submissions, 66 papers were presented in 20 parallel sessions. Furthermore, 6 selected posters were shown by their authors, and 5 keynote speakers and 4 round-table panellists took part. Another 13 people participated in plenary sessions and 20 in parallel sessions as chairs or with other key functions, making a total of 108 people (some of those having more than a role) with active roles in the programme. A background document was provided to the attendees prior to the conference, and after the conference a briefing document gave the main results of the conference (see Amoroso et al., 2019; Moncada-Paternò-Castello et al., 2019).

Findings

Overall CONCORDi 2019 paved the way to policy-relevant research avenues in several crucial aspects. In particular, with respect to the mapping of new technologies and the role of innovation in leading socioeconomic transformation, the conference provided a place to develop and discuss a research agenda shared by the international community of practitioners and academics dealing with the economics of industrial innovation and related policy issues.

The main findings can be summarised as follows.

New technologies, structural change, and industrial transformation

Both manufacturing and service industries are facing production, productivity and globalisation challenges driven by solutions based on radical innovation. Several countries have created policies to steer the development of Industry 4.0[40] and foster the adoption of digital technologies such as the 'High-yech strategy 2020' in Germany (where the concept of Industry 4.0 was born), 'Advanced manufacturing partnership' in the United States and 'Made in China 2025'. However, the adoption of these technologies is challenging for many firms and regions, mainly SMEs and productivity laggards. There is an increasing need for new management practices to fully embrace and reap the benefits of industry 4.0, moving towards a more integrated and digitalised productive structure.

Recent (new) scientific results of CONCORDi 2019 point out that, despite convergent tendencies, the deployment of industrial robots in Europe is deeply embedded in path-dependent industrial dynamics and developmental differences, and robot-based automation seems to strengthen the pre-existing territorial-economic disparities.

The latest robotic technologies are likely to displace labour in areas such as manufacturing, logistics, healthcare and routinised conceptual professions. However, there are considerable differences between countries in the intensity of robot usage, and also in the diversity of applications. A trade-off emerges between displacement of certain tasks and job-creating complementarities in others. In addition, at firm level there are significant differences between digital and non-digital companies, with the former more likely to innovate, increase employment or enjoy greater market power ([41]). This is particularly true in the service sector, where adoption of digital technologies is linked to service innovation.

The new JRC-OECD report (Dernis *et al.*, 2019) launched at the conference confirmed that the 2 000 top corporate R & D investors in the world are shaping the future of technology and AI ([42]). With regard to AI-related developments, firms in the ICT sector located in China, Korea and Japan, take the lead, while European companies rank higher in terms of basic research in the field. The analysis also shows the pervasiveness of AI-related technologies and their fast diffusion in non-ICT-related sectors.

Large MNCs play a role in the setting up and shaping of different types of GVCs. Understanding the geographical dimension of the innovation process is key, given that participation in GVCs shapes industrial structure at the local level. The geographical dimension is also essential in the process of creating and disseminating AI-related knowledge.

[40] The Fourth Industrial Revolution (or Industry 4.0) is the ongoing automation of traditional manufacturing and industrial practices, using modern smart technology

[41] There are several teams within the JRC, as in Unit B.4, that work on robotisation / automation and its impact on the labour market; see for example Antón *et al.* (2020).

[42] They own almost two thirds of patents filed at the largest IP offices worldwide.

Industrial innovation and socioeconomic transformation

The acceleration of technological change, urbanisation, an ageing society and increased global connections have a significant impact on the European socioeconomic model. As a consequence, this model faces several challenges: regional disparities, skills erosion, job losses, increasing inequality and environmental degradation. Therefore, the policy focus is shifting from purely economic growth to the broader concept of prosperity, which embraces sustainability objectives and puts employment and participation in the job market at the forefront of socioeconomic policies.

Scientific evidence presented during CONCORDi 2019 points to four messages relevant to policy.

First, R & D & I, the digital transformation and the pervasive diffusion of AI have mixed consequences for the labour force and structural inequalities. Some forms of innovation seem to favour employment and wage growth, while others lead to the loss of jobs. In fact, the effects of innovation and digitalisation are highly heterogeneous, varying across firms and sectors, and may have positive indirect effects through the emergence of new sectors, new forms of production and products, and new complementarities between AI applications and human tasks.

Second, sustainable technologies may have a significant impact on employment and industrial composition, and EU regions' related specialisation in environmental technologies may increase the labour market participation rate and investment in R & D and human capital.

Third, the transition to a circular economy calls for the development of industrial symbiosis: the mutually beneficial exchange of waste and by-products between geographically close agents.

Fourth, policies should foster sectors and firms in which labour-friendly product innovation is more prominent, while safety nets and lifelong learning programmes should be designed for those traditional and low-tech sectors where job losses due to automation are likely to be concentrated.

Intangibles and diffusion of technology for transformation

Technological diffusion relates to both geographical diffusion and diffusion from firm to firm as well as from technological fields to related fields. The deeply intertwined nature of technologies and other external factors make measuring the diffusion of technology a difficult endeavour. Several new measurements of technology diffusion were presented during CONCORDi 2019.

Most measurements are based on trade (e.g. the use of technologies embodied in intermediate goods), spillovers (patent citations, the choice of location of MNCs' R & D facilities, the impact of R & D on total factor productivity) and distance-to-frontier measurements (technology flows from leading firms to lagging firms). Trademarks look promising as a proxy for innovation in services. Furthermore, as most measuring strategies do not measure technology adoption, surveys may provide more insights, provided that they contain technology-specific information.

Many policy-relevant takeaway messages emerged regarding the barriers to technological diffusion and the policies aimed at overcoming them. On the one hand, technology diffusion is strongly affected by regulatory frameworks. Improved regulations such as capital, product and labour market regulations might improve the process of lagging firms catching up. On the other hand, many policy instruments fail to consider the absorption capacity of firms and regions, and the complementary nature of organisational capabilities.

If the policy issues are to be tackled empirically, two related questions need to be answered: how to trigger private investments in new technologies and how to encourage private firms to contribute to the collective exploration of new innovation pathways.

Evidence required for transformative industrial innovation policy

The result of this work also highlights important gaps in our present knowledge, in particular with respect to the interactions between firms' value chains and industrial innovation, and the interactions between humans and innovation, in both directions: the role of human capital and skills in unlocking regional innovation potential is central. A further crucial aspect that should be at the centre of future academic analysis, and is still not fully studied, is experimentation with and evaluation of new policies related to industrial transformation. One of the indications brought up in the conference is that the increasingly cross-disciplinary nature of the economics of industrial innovation calls for new statistical norms, new data, complex analytical methods and new policy designs that are able to consider the multidimensional (geographical, institutional, sectoral) aspects of the development of industrial innovation for transformation in Europe.

Contribution to science and policy, and practical implications

On the policy side, considering the scarce financial and environmental resources and the need to match industrial competitiveness and sustainability, new (disruptive) policies for transformation should be set up. The objective is to get private European companies to explore new innovations with the highest expected social return.

The main policy areas highlighted were (a) productivity slowdown and, in particular, the diffusion of technology versus pushing the technological frontier; (b) business creation and growth; (c) new efficient ways to stimulate innovation; (d) investment in human capital; and (e) competition and uneven distribution of wealth. Some specific policy initiatives were pointed out as follows.

Improved regulatory frameworks, access to VC and initiatives to strengthen human capital (the European Social Fund, the European skills agenda and Skills Intelligence) are important for stimulating both innovation and the business environment. In addition, country-specific recommendations and national productivity boards will help individual countries to analyse specific developments in and challenges to economic productivity and competitiveness.

'Co-creation' has a key role for achieving responsible R & I. Co-creation means collective responsibility for Horizon Europe, in which multiple actors and stakeholders will focus on shared objectives. The key action areas are investment in R & D, improved regulation through co-creation, and identification of national strategies and advisory boards.

An important EU objective is to close the digital skills gaps across Europe. Through its Digital Skills and Jobs Coalition action, the European Commission seeks to reduce these gaps further by fostering the sharing, replication and upscaling of best practices in areas such as training and enhanced matching for digital jobs, increasing certification and awareness. Major EU initiatives are expected to unlock even more of the EU's digital potential.

In this policy framework, the promotion of an innovative and smart economic transformation through the EU cohesion policy becomes crucial.

More information on results, the contribution to science and policy, and practical implications can be found in Amoroso *et al.* (2019) and Moncada-Paternò-Castello *et al*. (2019).

11.3 Limitations, follow-up and further collaborations

One limitation of the conference series is the low number of industrialists who attend the events. They are wanted, as they could validate or comment on some of the most recent research findings and policy initiatives and share their experiences in industrial innovation.

As follow-up, the editorial board of the *Journal of Technology Transfer* has accepted a proposal for a special issue on 'Technological relatedness and industrial transformation' containing a number of selected papers presented at CONCORDi 2019. It is planned to appear by autumn 2021.

Furthermore, the next edition of the biennial conference is planned to take place in autumn 2021, and the preparatory work started in summer 2020. The OECD, the United Nations Industrial Development Organization (UNIDO) and the European Association of Research and Technology Organisations (EARTO) will take part as collaborating organisations in CONCORDi 2021. Within the JRC, in practice all units of Directorate B are possible contributors, as well as colleagues from other directorates, notably from Directorates A and C.

References

Amoroso, S., Csefalvay, Z., Dosso, M., Gkotsis, P., Grassano, N., Moncada-Paternò-Castello, P., Pontikakis, D., Potters, L. and Pugliese, E. (2019), 'Industrial and innovation for transformation: New science and policy insights', *Industrial R & D – JRC Policy Insights*, No JRC118831.

Antón, J., Klenert, D., Fernández-Macías, E., Urzì Brancati, M. C. and Alaveras, G. (2020), *The Labour Market Impact of Robotisation in Europe*, Seville, European Commission, JRC121388.

Dernis, H., Gkotsis, P., Grassano, N., Nakazato, S., Squicciarini, M., van Beuzekom, B., & Vezzani, A. (2019). *World Corporate Top R&D investors: Shaping the Future of Technologies and of AI* (No. JRC117068). Joint Research Centre (Seville site).

Moncada-Paternò-Castello, P., Amoroso, S., Ponticakis, D., Pugliese, E. and Tuebke, A. (2019), *Industrial innovation for transformation – 7th European Conference on Corporate R & D and Innovation CONCORDi 2019 – Background note*, JRC Technical Report, EUR 29842 EN, Seville, European Commission, doi:10.2760/963644.

12. Summary and conclusions

12.1. Summary of main Joint Research Centre scientific contributions to support European Union policies

This section provides a synthesis of selected scientific results that have been introduced in the previous 10 chapters and their relevance to EU policies. These contributions are grouped in seven main thematic areas, which mirror the areas identified in the introduction (Section 1.3) in which evidence is required for the new industrial innovation policy.

Technology diffusion and industrial dynamics

The results of a study on **regulations and technology diffusion in Europe: the role of industry dynamics** (Chapter 4), implemented jointly by the JRC and DG Research and Innovation, suggest that the regulatory models have to account for specific characteristics of the market (e.g. labour, financial, demand for technological goods and services) and sectoral structure (i.e. sector composition of the economy).. Furthermore, they show that the excessive product market regulation tends to hinder technology diffusion in industries with vigorous business dynamism and high churn rates, in which innovation is driven by new entrants. Findings for labour market regulation suggest a more prudent view than merely advocating *tout court* deregulation of labour market relationships. Human capital and access to finance are confirmed as cross-cutting drivers of technology catch-up and diffusion.

Policies that specifically address regulation and diffusion directly are key in increasing the adoption rate of innovations, enabling local R & I systems to produce, absorb and implement new knowledge, ensuring that they keep pace with global technological change.

Industrial innovation and companies' value chains

The TRLs approach is relevant to mapping the **functional decomposition of companies' R & D value chains** (Chapter 4). The JRC work for DG Research and Innovation found that fast-developing local strengths of Asian countries – such as China, Japan and South Korea – in the automotive sector, and in electronics and related fields, are shaping companies' geographical localisation of R & D and innovation activities. While the EU has strong value chains in, for example, the automotive (network of combustion engine) and pharmaceutical (highly skilled labour force and strong research institutions) sectors, corporate R & D & I investments are finding their way to novel applications in emerging technologies in Asia.

The analysis of **productivity transmission through value chains** (Chapter 6) provides an insightful approach on how worldwide productivity developments are transmitted through global value chains from upstream to downstream activities. The developed decomposition makes it possible to identify the factors driving changes of overall efficiency in value chains, in particular changes in 'factor requirements' (e.g. driving the geographical relocation of production stages) relative to the role of shifts in the composition of value added. This analysis indicates that the reshoring of production to more efficient EU production units would require persistent innovation activities, e.g. scientific R & D, software development or IT services.

These results are central for R & I policies supporting local industrial and innovation ecosystems and clusters, and for identifying and integrating them into strategic value chains. The EU single market would benefit from a push to competition and efficiency in business services, which would spread to the rest of the economy through value chains, and the building of capacities and innovation in critical activities for overall productivity growth, such as electronic hardware, robotics, digitalisation and software development

Financing innovation

The research into **public grants and venture capital** (Chapter 7) reveals that considerable differences exist between the volumes and patterns of funding of innovative firms provided by public and private entities. Since its introduction, Horizon 2020's SME instrument has become an important source of public funding for SMEs in the EU. European companies looking for external funding frequently make use of both public and private sources of financing. For firms receiving public grants, early-stage investments represent the most important source of venture capital (VC) funding, followed by later stages. Substantial qualitative differences emerge between firms receiving private and public financing, in terms of both size and age: public entities providing funding to innovative companies target mainly relatively mature and large firms. Policies should therefore address different types of funding targeting different types of firms. It is also suggested that public authorities and private investors should cooperate more in financing the start-up and launch of young SMEs in the EU.

Some studies investigated **the role of venture capital in the financing of companies with high growth potential** (Chapter 8). A thorough understanding of the VC market in Europe was gained through an analysis of three different VC data sources. Empirical evidence confirms that countries and regions in Europe need all three forms of finance – seed finance, start-up capital and growth capital – for the emergence of companies with growth potential. There is also evidence that the categories of finance most adversely affected by the COVID-19 crisis are seed and early finance deals, whereas late-stage deals show much greater resilience..

The research streams on **R & I and taxation** (Chapter 3) focused, in particular, on the impact of a minimum digital tax on multinational profits and the reallocation of taxing rights due to the dematerialisation of the economy. The analysis was implemented by extending the original computable general equilibrium CORTAX model to include the R & D sector and evaluate digital taxation. The main results indicate, for example, that patent boxes reduce the impact of high effective tax rates, which lower the number of patents registered in a given country. Furthermore, the size of the digital sector in a country tends to be negatively related to the changes in CIT revenues. This is more pronounced the larger the share of non-routine profits.

From a policy perspective, these findings on the 'Financing Innovation' area provide some insights (as specified above, including their specific policy implications) into how public authorities and private investors cooperate in financing start-ups, young SMEs and companies with high growth potential in the EU. The results may be of interest, for example, for the European Innovation Council's Accelerator (previously the SME instrument), which supports top-class innovators, entrepreneurs and small companies with funding opportunities and acceleration services. The findings may also be relevant to the InvestEU programme's additional investment planned in four main areas: sustainable infrastructure; research, innovation and digitisation; SMEs; and social investment and skills. Part of this work already contributes to activities related to the European Semester, and can potentially be used to promote policy intervention in each EU country and inform the European Court of Auditors's activity report on VC, as well as being of interest to regional policymakers. The results of the analysis of the effects of 'patent boxes' on tax regimes are relevant for DG Taxation and Customs Union's proposal on the Common Consolidated Corporate Tax Base reform. The analyses of evaluating digital taxation are very novel, and very relevant to DG Taxation and Customs Union and the EU Member States.

Industrial innovation for transitions and transformation

Global impulses such as climate change and digitalisation call for pervasive industrial transitions. The European Green Deal provides legal certainty and resources. However, realising the promise of the European Green Deal hinges on evidence about territory-specific opportunities and pathways for realising them, which is not readily available. The **POINT** activity (Chapter 10) has set up a methodology for reviews of industrial transition that can provide evidence in support of system-level innovation, including about relations between sectors, governance structures, coordination regimes and ways of mobilising resources. All reviews provide actionable advice and can be applied at both the regional and the national level, building on the JRC's experience and pilot reviews of Andalusia, Bulgaria, Greece and Romania.

New challenges and aspects of policies for **innovation for industrial transformation** (Chapter 11) were identified as follows. Most recent innovations and integrated production structures need updated management practices. Territorial and economic disparities, and heterogeneous performance of firms, depend on the differences in innovation diffusion and adoption rates. The mixed consequences for the labour force and structural inequalities arise out of advanced digitalisation, while sustainable technologies may have a large positive impact on jobs and industrial composition. The disruptive transformative EU policies should be set up to trigger the exploration of innovation with the highest possible economic, social and employment returns.

The research activity of **digital transformation and AI** (Chapter 9) addressed the dramatic changes taking place in the economy and society. The related analysis covers a wide scope of activities and outcomes. For example, they reveal that the adoption of APIs in organisations catalyses digital transformation processes, fosters innovative processes with relatively low investment efforts, produces efficiency gains, and enables digital interactions with internal and external actors. This project has provided the first ever evidence of the roles and strategies that some digital platforms employ to leverage their dominant positions vis-à-vis their different groups of users.

These activities have provided evidence to support EU policy initiatives in the area of transformation and transitions, for example the EU Better Regulation and digital single market strategy goals, and the political priority 'A Europe fit for the digital age'.

Employment and skills for industrial transformations

A systematic review of present **policy responses to the impacts of robotisation and automation on the labour market** (Chapter 9) – i.e. redistributing the benefits of technological changes, increasing access to the benefits and utilisation of changes, and supporting the individual and institutional adjustment to changes – shows that all such policy responses raise further questions and challenges that should be carefully investigated in order to choose the right policy mix. The findings of the study of **labour mobility from R & D-intensive MNCs** in Denmark and the implications for knowledge and technology (Chapter 4) indicate that employees are more inclined to move between R & D-intensive MNCs and their subsidiaries than between these firms and other firms in the economy. This is particularly true of highly skilled employees. The results suggest that R & D-intensive MNCs and their subsidiaries form a kind of submarket within the national labour market.

These findings could provide analytical support to the new European skills agenda, which sets an EU-wide framework (July 2020; European Commission, 2020a). This skills policy strategy aims to underpin talent supply, enable the development of advanced technologies, and help match new skills with labour market needs as encompassed in the European Commission communication 'A new industrial strategy for Europe' (European Commission, 2020b).

Integration of global to local industrial innovation perspectives

The findings of the studies on **internationalisation of R & D, regional integration and local innovation** (Chapter 2) reveal that EU, national and local policies may create favourable conditions for attracting FDI in R & D. Yet the beneficial spillover effects on receiving areas, often assumed in previous studies, require closer empirical scrutiny. Investments concentrate in hub locations, which on the one hand raises concerns related to increasing regional inequality, and on the other hand positively contributes to connecting distant locations and fragmented innovation systems.

These findings support the role of EU policy instruments aimed at creating an integrated European R & I area, as well as regional development and industrial competitiveness.

Data, measurements and methods for the new innovation policy

The JRC has implemented advanced collection and use of **data** in recent years. Examples are the data set with matched data from VentureSource (Dow Jones), the SME instrument programme (European Commission) and ORBIS micro data (Bureau van Dijk) for the analysis of public grants and VC investments; the matching of patent data from the European Union Intellectual Property Office with company data from the EU R & D Scoreboard (COR&DIP Database to analyse the evolution of technology innovation in the EU and benchmark it against competitors; the data collection for VC analyses such as Invest Europe, VentureSource, Dealroom and Pitchbook; and the data set of investments (fDi Intelligence, Zephyr) complemented with other various data sources (Eurostat, OECD, Cambridge Econometrics, etc.), providing information of interest at a local level; and the extension of the CORTAX data set for digital taxation. The JRC teams also produced new **quantitative indicators**, e.g. to explore technology-driven segments of the economy to support digital transformation policies.

JRC activities are also devoted to preparing better measurement methods for drawing up EU industrial innovation competition **standards** to help realise an integrated internal market and to protect the EU's interests globally, which are key factors that will shape the EU's industrial innovation policy. One example is the definition and taxonomy of AI.

A new **methodology** was developed to deal with complexity analyses (Chapter 5) of territorial industrial innovation and competitiveness. The main strength of the methodology is the provision of disaggregated analyses of specific sectors while maintaining a quantitative and homogeneous methodology. Using data characterising trade activity and innovation systems, the methodology can inform regional and national stakeholders of future trajectories and highlight emerging opportunities. Other examples are the setting up of a new methodology to assess the European robotics market (Chapter 9), and the POINT methodology (Chapter 10).

These are essential analytical tools to adequately support EU policymaking in industrial innovation, such as 'A new industrial strategy', ERA / Horizon Europe and regional-related policies, in particular with respect to RIS4. Moreover, the development of such new data sets is well aligned with the European data strategy's objective of making the EU a leader in a data-driven society (European Commission, 2020c).

12.2. Concluding remarks

Future science for policy initiatives should place a strong emphasis on the analysis of industrial innovation ecosystems, their current state, the impact of COVID-19, problems faced in the internal market, and building a pathway towards a green, digital and resilient future for the EU. Technology and industrial innovation activities should ensure the link between the key societal challenges and the European economy towards more and better growth, environmental sustainability and jobs.

However, the speed and complexity of recent technological, industrial and social changes pose fundamental challenges to industry and to Europe's capacity to sustain appropriate levels of job creation and economic growth. The EU should turn its weaknesses into strengths by better targeting and tailoring R & I and industrial policies to EU-specific conditions. This can guarantee that efforts to accelerate growth and competitiveness will not fail to turn ideas into actions. Tailoring also means that different instruments should be set up to address different challenges. Sometimes large firms would be crucial to realise the innovation mission, while in other cases SMEs or new technology-based firms would be the essential targets, as they are often concentrated in newer high-knowledge-intensity and growing sectors.

These findings reveal that, to achieve a more positive industrial innovation dynamic, the EU should aim for a different sector mix with a larger presence of younger firms in new(er) R & I-intensive sectors. This would reduce both the EU's industrial R & I intensity and competitiveness gaps vis-à-vis its main competitor(s). Furthermore, there is still too little capacity in the EU to transfer R & I results into the economy, and it happens too slowly. Therefore, EU policies should address barriers that firms encounter to developing and absorbing innovative solutions, entering R & I-intensive sectors, and growing.

Moreover, as the industrial structure matters, policy should take it into account. In an EU where industrial specialisation differs substantially across EU countries and regions, a sensible policy strategy should also consider the industrial specificities, seeking to encourage specific patterns of specialisation.

Appropriate focus of policy objectives and the integration and coordination of policy instruments have become even more important in recent times. Possible ways to increase synergies between EU instruments – such as those recently announced to restore the European economy from the recent pandemic crisis – can be realised in line with 'A new industrial strategy for Europe' (European Commission, 2020b) which aims to transform European industry and make it greener, more circular and more digital, while remaining competitive on the global stage, and in which innovation represents one of the key factors to support the related industrial transformation ([43]). Such synergies can be implemented in line with Horizon Europe, by extending, for example, the application of strategic innovation agendas. At national and regional levels, it would be suitable to strengthen R & I in EU industrial ecosystems, implement and deepen industry-relevant EU Semester priorities in R & I, and foster smart specialisation, including the follow-up to Platform for Industrial Modernisation and the Knowledge and Innovation Communities of the European Institute of Innovation & Technology ([44]).

The challenge for EU policymakers becomes how to integrate company, industrial sector and territorial innovation specificities into tailored policies and instruments based on a shared European vision.

12.3. Lesson learned, and the way forward

The JRC's 2-year (2019–20) experience of contributing to the "technological and innovation challenges for industry 2030 strategy" (TIC 2030 strategy) confirms that the following ingredients will be essential in future to make the JRC's science for policy activities in this area even more efficient and impactful.

First, a **JRC strategic intent** related to its scientific support to the new EU industrial innovation policy should be confirmed and communicated. Second, both the JRC and the main policy DGs should **rely on new data, new analytical instruments, and updated expertise and skills**. Third, the **collaboration and integration** within the JRC, and between the JRC's external experts and other European Commission policy services, should be assured. These ingredients should be already in place at the start of the conception of the science for policy activities, and can be facilitated by structured and long-term work programmes across teams and services of the European Commission.

([43]) https://ec.europa.eu/growth/

([44]) https://ec.europa.eu/info/research-and-innovation_en

The work presented here is part of the JRC work programme 2019–2020. It should be pointed out, however, that during 2020 the European policy and scientific agenda changed dramatically and, with it, the JRC oriented the work streams and objectives towards, among other things, the new EU industrial strategy, the Green Deal and its twin transition objectives settled in 2020. The results of this new orientation will become more visible in the course of 2021.

The continuation of the TIC 2030 strategy is assured by the Industrial Innovation for the Green Deal, Strategy and Coordination project (2021–2022), which aims to tackle the new science for policy challenges. The objective is to make full use of the JRC's internal capacity for critical industrial and technology innovation issues to better support the European Commission's policy services. The project can well address key aspects of industrial innovation, such as the cross-sectoral nature, the multigeographical reach and the three dimensions (economic, social and environmental) of sustainability.

References

European Commission (2020a), Commission communication – 'European skills agenda for sustainable competitiveness, social fairness and resilience' (COM(2020) 274 final)

European Commission (2020b), Commission communication – 'A new industrial strategy for Europe' (COM(2020) 102 final)

European Commission (2020c), Commission communication – 'A European strategy for data' (COM(2020) 66 final)

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