Responsible Research and Innovation approach for transitioning the traditional industry regions into digitalised industry territories.

Deliverable Title: **D2.3 Description of the R&I ecosystem landscapes of each of the three territories**

Work Package: **WP2 Stocktaking / Mapping**

V1.1 Final revised

Lead beneficiary: **AIT Austrian Institute of Technology GmbH (AIT)**

Date: **30 September 2020**

Nature: Report | Diss. level: PU (Public)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 873010.

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DOCUMENT INFORMATION

Grant Agreement Number	873010	Acronym	DigiTeRRI
Full title	Responsible Research and Innovation approach for transitioning the traditional industry regions into digitalised industry territories.		
Project URL	www.digiterri.eu		
EU Project officer	Cristina Marcone		

Deliverable number: D2.2	Title	Data collection report
Work package number: WP2	Title	Stocktaking / Mapping

Delivery date	Contractual	31 July 2020	Actual	30 September 2020
Status	Draft/Concept	Version: V1.1	Draft ☐	Final ☑
Nature		ORDP ☐ Report ☑ Websites ☐ Ethics ☐		
Dissemination Level		Public ☑ Confidential ☐		

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Description of the deliverable (3-5 lines)	Mapping of the territorial R&I ecosystems Grand Est, Styria and Värmland in a comparative perspective, with respect to (i) R&I governance, strategies and actors, and (ii) regarding their R&I activities and the role of digitalisation therein
Keywords	R&I ecosystems, territories, institutional mapping; digitalisation, scientific publication, R&I collaborations, technological specialization; descriptive analysis, network analysis, science mapping

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 873010.

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DOCUMENT HISTORY

NAME	DATE	VERSION	DESCRIPTION
D2.3_DigiTeRRI_V0.1_MP.docx	24 Jul 2020	V0.1	Draft concept (CO)
D2.3_DigiTeRRI_V0.2.docx	25 Sep 2020	V0.2	Draft for review (CO)
D2.3_DigiTeRRI_V0.9.docx	29 Sep 2020	V0.9	Revised version (CO)
D2.3_DigiTeRRI_Description_of_the_R&I_ecosystem_landscapes_V1.0.docx	30 Sep 2020	V1.0	Final (PU)
D2.3_DigiTeRRI_Description_of_the_R&I_ecosystem_landscapes_V1.1.docx	4 Nov 2020	V1.1	Final revised (PU)

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DEFINITIONS & ACRONYMS

DEFINITIONS

DEFINIENDUM	DEFINIENS
Digitalised industry territories	Territories with a high level of digitalisation in their industrial sectors, i.e. a high level of digital development and usage of ICT innovations, taking into account technical, business and social elements (see, e.g., Grundke et al. 2018)
Industry 4.0	Fourth Industrial Revolution (or Industry 4.0) is the ongoing automation of traditional manufacturing and industrial practices, using machine-to-machine communication (M2M) and the internet of things (IoT).
Jaccard-Index	A statistic used for measuring the similarity of finite sample sets (Rip and Courtial 1984).
Regional Innovation Scoreboard	The regional innovation scoreboard (RIS) is a regional extension of the European innovation scoreboard, assessing the innovation performance of European regions on a limited number of indicators. The RIS 2019 covers 238 regions across 23 EU countries, Norway, Serbia andd Switzerland. In addition, Cyprus, Estonia, Latvia, Luxembourg, and Malta are included at country level.
RRI	Responsible research and innovation (RRI) is defined as an inclusive approach to R&I, to ensure that societal actors work together to better align both the processes and outcomes of R&I, with the values, needs and expectations of the society. The concept originated from the European Commission's Directorate-General for Research and Innovation (DG RTD) around 2011 and has been widely used since then in European R&I policy, especially as a cross-cutting issue in the EU´s Horizon 2020 programme (Owen et al. 2012).
R&I ecosystem	Research and Innovation (R&I) ecosystems are represented by a complex interplay between academic and business actors as well as the public sector and being connected in networks of research, development and innovation activities supported by public policy mechanisms (Tondelli et al. 2019).

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Territory	A territory is defined as any geographical area characterized by certain geographical features, or shared cultural, environmental, or economic ties (Magnaghi & Kerr 2005).
Triple Helix	The triple helix model of innovation refers to a set of interactions between university, industry and government, to foster economic and social development (see, e.g., Leydesdorff & Etzkowitz 1996).

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ACRONYMS

TERM	EXPLANATION
BibTechMon	Software tool developed by AIT Austrian Institute of Technology GmbH for structuring, visualising and analysing the content of large amounts of data, e.g. text-based analysis of publications, patents etc.
DESI	Digital Economy and Society Index; a composite index that summarises relevant indicators on Europe's digital performance and tracks the evolution of EU Member States in digital competitiveness (https://ec.europa.eu/digital-single-market/en/desi)
ERDF	European Regional Development Fund; a fund allocated by the European Union to invest in the infrastructure and services of underdeveloped regions
EU-FP	European Framework Programme (e.g. Horizon 2020)
EUPRO	Database of EU-FP projects, 1984 to date; (https://rcf.risis2.eu/dataset/4/metadata)
EUROSTAT	Eurostat is the statistical office of the European Union (https://ec.europa.eu/eurostat/).
GDP	Gross domestic product; the total value of goods produced and services provided in an economy during one year
H2020	Horizon 2020, current EU-FP (2014-20)
ICT	Information and communication technology
INTERREG	A series of programmes to stimulate cooperation between regions in and out of the European Union (EU), funded by the European Regional Development Fund.
IPC	The International Patent Classification (IPC) provides for a hierarchical system of language independent symbols for the classification of patents and utility models (https://www.wipo.int/classifications/ipc/en/)
ISCED	International Standard Classification of Education; a statistical framework for organizing information on education maintained by the United Nations Educational, Scientific and Cultural Organization (UNESCO)
MoRRI	H2020 project "Monitoring the Evolution and Benefits of Responsible Research and Innovation" (Ravn et al. 2015)
NUTS	Classification of territorial units for statistics (EUROSTAT)
OECD	Organisation for Economic Co-operation and Development, an intergovernmental economic organisation with 37 member countries (high-income economies)

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S3	Smart Specialization Strategy of the European Commission (https://s3platform.jrc.ec.europa.eu/)
SSH	Social Sciences and Humanities (cross-cutting issue in the EU-FPs, comprising non-technical disciplines such as sociology, economics, psychology, political science, history and cultural sciences)
PATSTAT	Worldwide patent statistical database, maintained by the European Patent Office (www.epo.org)
PCT	Patent Cooperation Treaty; international treaty that makes it possible to seek patent protection for an invention simultaneously in more than 150 contracting states
RIS3	Regional Strategy for Research and Innovation for Smart Specialisation (S3)
RISIS	European Research Infrastructure for Science, Technology and Innovation Policy Studies (https://www.risis2.eu)
RTA	Revealed Technological Advantage; relative technological specialization of regions, e.g. measured in terms of patent applications (Soete & Wyatt 1983)
SeeRRI	H2020 project “Building Self-Sustaining Research and Innovation Ecosystems in Europe through Responsible Research and Innovation”, Grant Agreement No. 824588
SNA	Social Network Analysis; a graph-theoretical and visualization method that describes networked structures in terms of nodes (e.g. organizations, authors, keywords) and edges (e.g. association, co-authorship, co-occurrence) that connect them (Wasserman & Faust 1994)
WoS	Web of Science; a web resource which provides subscription-based access to multiple databases that provide comprehensive citation data for many different academic disciplines maintained by Clarivate Analytics (https://apps.webofknowledge.com/)

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EXECUTIVE SUMMARY

DigiTeRRI aims at contributing to the transition of **traditional industry regions** into **digitalised industry territories** in Europe. To this end, the project focuses on three typical case regions, namely **Région Grand Est** in France, **Styria** in Southern Austria and **Värmland** in West Middle Sweden and **develops as well as implements roadmaps** for the transition. DigiTeRRI addresses this challenge by adopting an "Responsible Research and Innovation (RRI)" approach, by co-creating territory-specific visions, conducting a roadmapping process and implementing actions, while tapping cross-territorial learning potentials.

To support this process from the outset, a sound empirical basis is laid through a **systematic mapping of the three R&I ecosystems**, conducted in Workpackage 2, comprising qualitative and quantitative aspects. In its comprehensive empirical approach, the mapping in DigiTeRRI is an **original multiscale approach** about digitalisation and RRI. The different study levels are (i) the territory with their **stakeholders and means** (universities, companies…), (ii) the **territorial ecosystems** as represented by the stakeholders involved in digitalisation with their strategies, networks and current outcomes, and (iii) the **territories in action**, focusing on current **local initiatives** to foster digitalisation. Regarding (iii), the mapping focuses on ongoing digitalisation practices, involved actors and maturity levels of digitalisation, building on an online survey among stakeholders, which is presented in a separate report (Boly et al. 2020, Deliverable D2.4). Complementary to that, the current report focuses on (i) and (ii) with quantitative methods to describe the R&I ecosystems in the territories drawing upon existing databases and web resources to present indicators of the status and activities in digitalisation.

The **objective** of this report (Deliverable D2.3) is **to present the results of the quantitative mapping** of the territorial R&I ecosystems in DigiTeRRI – Grand Est, Styria and Värmland – in terms of:

- their **socio-economic background**,
- the most relevant **institutions**, **governance structures** and **strategies towards digitalisation**,
- and their R&I performance, including **scientific research**, **R&I collaborations** in regional, national and international networks and **technological profiles**.

The report is intended to characterize the **status quo of the respective R&I ecosystem** with a focus on digitalisation, analysing sectoral and organizational distributions within the territories as well as intraregional and extra-regional knowledge exchange networks and identifying the key actors in collaborative projects, patenting and scientific publishing.

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As a first step, we give a brief description of the **socio-economic profile** of the territories, referring to the **economic situation**, the **industrial structure**, **employment** aspects, **educational attainment**, and core figures of the **research and innovation** performance**.**

The second step is to characterize the R&I ecosystem from an institutional perspective. Starting from the **governance structure** including government and intermediary actors and their roles and responsibilities, we identify the most important development **strategies for the digital transformation** and strategies that consciously include or at least are conforming with **RRI** goals. Furthermore, actors and their activities in the **educational systems** in the region are described, and so are the most important **research and innovation** actors from the public and industry sectors.

The third step is to map the three R&I ecosystems with respect to their **R&I performance**. According to the conceptual approach (described in Stegmann McCallion and McCallion (2020), Deliverable D2.1), we refer to the aspects of **knowledge creation** in the region – measured by scientific publications –, **knowledge exchange** within the regions and beyond – measured by collaborative R&I projects –, and **innovation-relevant output** – measured by patent applications. Hereby, we draw on a mix of descriptive and analytic methods:

- A **census of R&I formal artefacts** is provided by descriptive analysis. The R&I ecosystems are characterized in terms of the publications, R&I projects, patents, actors and technological areas. Moreover, to reveal the structure and dynamics of scientific knowledge, we employ a sophisticated method, namely **Science Mapping,** i.e., the development and application of computational techniques to visualize, analyse and model a broad range of scientific and technological activities (see, e.g., Chen et al. 2014).
- **Social Network Analysis** (SNA) is applied to reveal the potential to access external knowledge through interactions between R&I actors (Wasserman & Faust 1994). Central to the SNA perspective is the notion of networks, built on collaborative relationships among R&I actors, and on patterns and implications of these relationships. In the context of this mapping, linkages between the actors, within and across regional boundaries are of relevance.
- The **Revealed Technological Advantage** (RTA) is an indicator of relative technological strength of a region and can make use, for instance, of patenting data (Soete & Wyatt 1983). Here, we use it to assess the internal knowledge base and capabilities, highlighting specialization patterns of the regions.

To this end, **large-scale global, and territory-specific R&I datasets** are used, covering different types of activities that support the digital transformation in the medium and long run, such as scientific publishing, R&I projects, patenting and funding activities. By this, a systematic view on the actor landscape and the topical structure of the digitalisation activities in the territories is presented for all three territories, Grand Est, Styria and

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Värmland. The **results on the territories** are described in such a way, that they **can be read and interpreted independently** from each other, while we use the same structure so that a comparative perspective is kept. Hence, this mapping is the starting point to provide a better understanding of the selected territorial R&I ecosystems and to support cross-territorial learning.

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CHAPTER 1: INTRODUCTION

DigiTeRRI aims at contributing to the development of sustainable digitalised R&I ecosystems in traditional industry territories in Europe. Its overall objective is thus to develop and implement roadmaps for transforming traditional industry regions into self-sustaining digitalised industrial R&I ecosystems. Three typical regions in this respect were selected for this endeavour, namely Région Grand Est in France, Styria in Southern Austria and Värmland in West Middle Sweden. They are characterized by traditional manufacturing and process industries like steel, wood and paper as well as mechanical engineering, especially automotive, rolling stock and aerospace supply, with an acknowledged need to catch up in the digital transformation process. DigiTeRRI addresses this challenge by adopting a “Responsible Research and Innovation (RRI)” approach, by co-creating territory-specific visions, conducting a roadmapping process and implementing actions in the territories, while tapping cross-territorial learning potentials.

To support a sound understanding of the involved territories for the later visioning and roadmapping process in DigiTeRRI, this report provides an initial mapping of the three R&I ecosystems. R&I ecosystems comprise the academic, business and public sector organizations, their innovation activities and, not least, the strong interactions within such complex systems – an aspect that legitimizes the use of the ecosystem metaphor.

Moreover, in DigiTeRRI we give the notion of R&I ecosystems special twist by highlighting digitalisation and its role as a game changer in economic, technological and even societal processes. Thus, this report focuses on those aspects of the innovation system, that are linked to the digitalisation, and keeping in mind that the ongoing process of digitalisation permeates all parts of the economy and society. In its comprehensive empirical approach, the mapping in DigiTeRRI is an original multiscale approach about digitalisation and RRI. The different study levels are (i) the territory with their stakeholders and means (universities, companies…), (ii) the territorial ecosystems as represented by the stakeholders involved in digitalisation with their strategies and current outcomes, and (iii) the terroritories in action, focusing on current local initiatives to foster digitalisation.

The aim of this report is to present the results of the systematic mapping of the territorial R&I ecosystems in DigiTeRRI – Grand Est, Styria and Värmland – in terms of:

- their socio-economic background,
- their institutions, governance and strategies towards digitalisation,
- and their R&I performance, including scientific research, collaborations in regional, national and international networks and technological profiles.

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This deliverable is intended to characterize the status quo of the respective R&I ecosystem with a focus on digitalisation, analysing sectoral and organizational distributions within the territories as well as intraregional and extra-regional knowledge exchange networks and identifying the key actors in collaborative projects, patenting and scientific publishing. To this end, large-scale global, and territory-specific R&I datasets were used, covering different types of research activities that support the digital transformation in the medium and long run, such as scientific publishing, R&I projects, patenting and funding activities. By this, a structural view on the actor-topic digitalisation landscape in the territories is presented, allowing to interpret them region-by-region but also from a comparative perspective. Hence, this mapping is the starting point to provide a better understanding of the selected territorial R&I ecosystems in terms of strategic priorities and means.

The report is structured as follows. Chapter 2 describes the conceptual and methodological approach for mapping the digitalisation-related aspects of the R&I ecosystems. Chapters 3, 4 and 5 present the actual results of the mapping and are structured in the same way so as to allow a comparative perspective on the three territories: (i) socio-economic background, (ii) institutional mapping, and (iii) R&I-performance in digitalisation. Chapter 6 concludes. Various supporting information used in the analysis can be found in the Annex. Note that Chapters 3 to 5 are structured in the same way, such that each of them can be read separately without any information given in the sections targeted at the other territories. Hence, any duplicated formulations are by intention.

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CHAPTER 2: THE MAPPING APPROACH

To allow for a solid characterization of the territories and to obtain cross-territorial comparability, a joint framework for qualitative and quantitative data collection was developed and documented in Deliverable D2.1 (Stegmann McCallion & McCallion 2020). A comprehensive set of indicators to characterize the R&I ecosystems was defined thereupon and required data sources were specified in detail at regional, national and supra-national levels in Deliverable D2.2. (Paier et al. 2020) to provide a solid empirical basis for the mapping.

The Research and Innovation (R&I) ecosystem is the subject of many definitions in the innovation literature but nevertheless a broadly used metaphor in R&I policy (e.g., Frenkel & Maital 2014, Oh et al. 2016). In the RRI context, R&I ecosystems refer to a complex interplay between academic, public sector and business actors being connected in networks via research, development and innovation activities supported by public policy mechanisms (Tondelli et al. 2019).

In this mapping, we focus on the digital transformation of the R&I ecosystems in Grand Est, Styria and Värmland and adopt a comparative perspective. It is therefore useful to describe in this Chapter the applied methods in a general form since they were applied to all the territories in the same way. The territorial delineation of each of the regions was undertaken using the NUTS classification (see Table 28 in the Annex). The exact territorial delineation is mainly needed for the correct geographical assignment of scientific publications, patents and research projects to the region. Postal codes on those documents are linked to the NUTS regions using concordance tables provided by EUROSTAT[1].

Our conceptual approach to characterize the three R&I ecosystems comprises therefore three different levels of description, namely, i) to sketch the socio-economic profile of the region, ii) to describe the governance structure of the region including the relevant R&I, digitalisation and RRI strategies in place, and an account of the actor landscape, and finally iii) to analyse the R&I activities that are related to digitalisation in the regions. We will apply the same procedure to describe all three territories in the identical structure given in Chapters 3, 4 and 5.

[1] The concordance tables used are “pc2018_fr_NUTS-2016_v1.0”, “pc2018_at_NUTS-2016_v1.0” and “pc2018_se_NUTS-2016_v1.0” are used. Accordingly, 1845 postal codes are identified for Grand Est, 344 postal codes for Styria, and 434 postal codes for Värmland.

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2.1 Socio-economic background

As a first step, we give a brief description of the **socio-economic profile of the territories** drawing on **descriptive statistics**. Referring to the general economic situation, the industrial structure, employment aspects, educational attainment, and research and innovation performance we underpin the later, more detailed characterization of the R&I ecosystems. Hereby, we refer to standard indicators drawing on existing databases to characterize the status and recent developments in the regions. The sources used are EUROSTAT, the Regional Innovation Monitor, the European Regional Innovation Scoreboard and distributed data from the regional authorities.

2.2 Institutional mapping

The second step is to characterize the R&I ecosystem at the institutional level. Beginning with the **governance structure**, we describe the most important stakeholders in the territory, government actors and intermediary actors and their roles and responsibilities for policy formulation, strategy development and implementation. **Economic development** strategies and plans that are relevant for the digital transformation, are mentioned and briefly sketched. Furthermore, actors and their activities in the **educational systems** in the region, ranging from secondary level, vocational training to higher education institutions are described, as well as the most important **research and innovation** actors from the public sector and from industry, alongside with the intermediary sector. Thus, three main points of view are adopted to detail the impact of these actors involved in an R&I ecosystem:

- The evaluation of **scientific publication activity** can be measured in terms of the scientific and technology documents that they produce and distribute. This production gives a good representation of the prior territorial strategic domains of digitalisation within the local ecosystems and indicates the core competence fields of the actors.
- The **R&I projects** they support allow to understand the territorial strategy about digitalisation, the main scientific and technological capabilities, and the strategic choices to exchange knowledge with external partners.
- The **collaboration** in the ecosystem gives a better understanding of the functioning modes to apply local political strategies.

As far as **digitalisation strategies** and RRI are concerned, we clearly remain at the policy level, listing the most important strategies and plans. Here we point out that the complementary perspective on concrete measures

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and practices is taken in a separate document, namely Deliverable D.2.4 (Boly et al. 2020), where an online survey was conducted to identify and characterize practices of digitalisation in the territories in detail.

RRI policies and strategies aim to support processes of transformation of the R&I system through better alignment with societal values, needs and concerns, and encourage a broad range of societal actors to work together during the whole research and innovation process. In the last couple of years, six key areas of RRI, i.e. gender equality, science literacy and education, public engagement, ethics, open access, and governance have been developed. Important projects in this respect are MoRRI (see Ravn et al. 2015) and SeeRRI (Tondelli et al. 2019). It has to be admitted, however, that quantitative data on RRI dimensions or keys is very sparse at the level of the territories, and therefore DigiTeRRI relies also here mostly on own field research that is being conducted in Task T2.4. The development of a corresponding harmonized monitoring system is currently on the way, to ensure cross-European data collection on the evolution and benefits of RRI (https://www.super-morri.eu/super-morri/). Since such a system to monitor the complex and diverse relationships between RRI policies and practices and their societal, democratic, economic, and scientific benefits is, however, not yet in place.

As compared with other RRI projects we point out that DigiTeRRI is an original multiscale approach about digitalisation and RRI, whereby we cover three different study levels:

i) the territory with their actors and means (universities, companies…),
ii) the territorial ecosystem comprising the stakeholders´ activities, strategies and current outcomes relevant for digitalisation,
iii) the territory in action, focusing on local initiatives to foster digitalisation.

Regarding (iii), DigiTeRRI contributes to this endeavour by collecting original information on RRI practices from the field through a survey (Deliverable D2.4, Boly et al. 2020). For the current report, Deliverable D2.3, we focus mostly on (i) and (ii), while regarding (iii) we restrict ourselves to the R&I strategy level in the regions and identify RRI activities from secondary sources.

As the main method we used desk and web research, plus additional targeted phone calls, gathering qualitative information from a broad range of sources, mainly from public authorities and administrative bodies at European, national and regional levels. Other sources were websites of agencies and owners of the different programs and measures, the Digital Economy and Society Index (DESI) and the European Regional Innovation Monitor.

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2.3 Methods for mapping R&I activities

The main challenges in mapping the three R&I ecosystems in the context of DigiTeRRI are twofold: First, it is difficult to specify the notion of digitalisation – which is used as a general term at the political and strategic level – in sufficient detail and bring it down to the level of R&I practice, by finding corresponding technical terms are needed to identify concrete activities. Second, we have to tackle the pervasiveness of digital technologies and their intricate role throughout the economy and society, which is still a debated issue (see, e.g., Ahmad & Ribarsky 2018). We therefore apply different methods to get a comprehensive picture of the R&I ecosystems in the territories:

i) The **census and analysis of formal artefacts in R&I**. This consists on the one hand of simple **descriptive analysis** of the R&I ecosystems in terms of publications, R&I projects and patents. These data are analysed to identify actors and their technological areas. On the other hand, **science mapping** is the development and application of computational techniques to the visualization, analysis, and modelling of a broad range of scientific and technological activities (see, e.g., Chen et al. 2014). Its central goal is to reveal the structure and dynamics of scientific knowledge, which is a quite sophisticated task.

ii) **Social Network Analysis** (SNA) is applied to reveal the access potential to external knowledge through interactions between R&I actors (Wasserman & Faust 1994). Central to the SNA perspective is the notion of networks, built on collaborative relationships (joint projects or publications representing the network links) among R&I actors (organizations or authors constituting the network nodes), and on patterns and implications of these relationships. In the context of this mapping, linkages between the actors, within and across regional boundaries are of relevance.

iii) The **Revealed Technological Advantage** (RTA) is an indicator of relative technological strength of a region and can make use, for instance, of patenting data (Soete & Wyatt 1983). Here, we use it to assess the internal knowledge base and capabilities, highlighting specialization patterns of the regions.

2.3.1 Science mapping

To analyse the scientific activity on digitalisation in the three regions we use publication data from the Web of Science (WoS) database[2] (Clarivate Analytics). The identification of a relevant selection of scientific articles for each region and the analysis of the corresponding bibliographic information was based on a specific data search

[2] https://apps.webofknowledge.com/

defining the geographic range, a suitable time period, and a relevant thematic focus for each territory. The procedures are described in detail in the next subsections and are visualized in Figure 1.

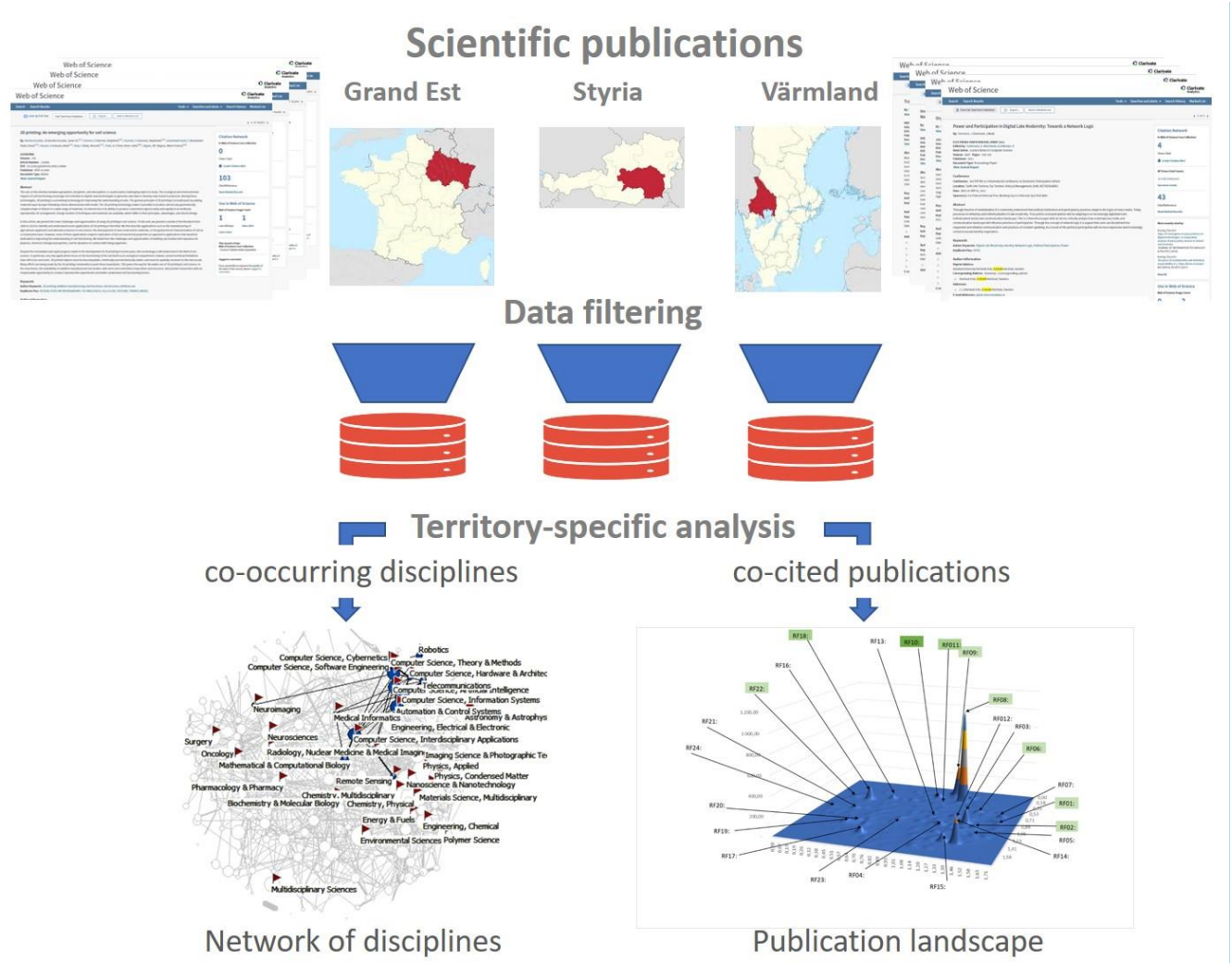

Figure 1. Procedure for science mapping in DigiTeRRI

Search and retrieval

Geographic range

The aim was to identify all relevant scientific research going on in the region that is relevant for digitalisation. Thus, as a first step, all publications with at least one author's affiliation from the region were downloaded. These publications were identified by corresponding postal codes of the territories. The publications were identified by

the postal codes in the Zip-code (ZP) field and downloaded from web of science in packages of 500 documents, which is the maximum number of downloaded papers at one request. The downloaded text files of one territory are then merged to one common text file in MS Word for each territory. This data is further processed with MS Excel and in a further step imported in MS Access.

Time period

We decided to focus on the most recent publications (2018-2020) from Grand Est and Styria, and a longer period for publications from Värmland (2010-2020). The reasons are i) to have a processable number of publications, and ii), since scientific work does not change abruptly from one year to another, is possible to grasp the current related research in a short recent time period. After a first inspection of the mere amount of relevant data, a minimum period of two full years was chosen because an important outlet in digitalisation-related scientific communities are conference papers, and many of the relevant conferences are biennial. This was considered appropriate for the larger regions Grand Est and Styria. For Värmland, however, due to the small size of the region, the regarded time period had to be expanded to the last 10 years to reap a sufficient number of publications for our analytic approach.

Thematic analysis

Digitalisation plays an important role in almost all research work at least in its application in form of digital instruments, computers, databases, and algorithms. We are dealing with a highly digitized research in general. Therefore, as a first step the entire publication activity in the three regions was surveyed. In a second step digitalisation research was defined as a specific area. For this, computer sciences in the broadest sense were taken into account.

This thematic delimitation was based on the selection of WoS Categories (provided by Clarivate) as being digitalisation relevant scientific disciplines. By expert judgement, a subset of the WoS Categories was selected as follows.

- Automation & Control Systems
- Computer Science, Artificial Intelligence
- Computer Science, Cybernetics
- Computer Science, Hardware & Architecture
- Computer Science, Information Systems
- Computer Science, Interdisciplinary Applications
- Computer Science, Software Engineering

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- Computer Science, Theory & Methods
- Imaging Science & Photographic Technology
- Mathematical & Computational Biology
- Medical Informatics
- Neuroimaging
- Radiology, Nuclear Medicine & Medical Imaging
- Remote Sensing
- Robotics
- Telecommunications

Based on the structured database for each of the territories in MS Access, further analysis and visualization of the publication data is conducted with the software BibTechMon (Kopcsa and Schiebel 2001). Disciplines, authors, affiliations, keywords and references were extracted from the relevant fields of the database. With BibTechMon, quantitative and qualitative analyses of scientific publications based on large datasets can be accomplished, and each of the territories are characterized from four different perspectives.

Science maps

A first complete overview of the digitalisation relevant scientific publication activities of the territories can be achieved with so-called science maps. These science maps are network diagrams of WoS Categories that are assigned to the publications by the Web of Science[3]. The fact that publications usually are assigned to more than one WoS Category, their co-occurrence on the publications can be used to construct networks of WoS Categories. We create the network graphs with BibTechMon, and with some editing features of the tool, we can depict the digitalisation-oriented publications of a territory in the context of their other publication activity. This analysis is based on pre-defined scientific disciplines.

Publication landscapes

A different insight into the publication activity can be gained with bibliographic coupling, using the citations given by the authors (i.e., without having to draw upon predefined categories like in the Science maps). We call this method “publication landscapes”, and it is employed for the creation of Figure 4, Figure 9 and Figure 14.

[3] https://apps.webofknowledge.com/

Accordingly, the basis of this method is the set of publications with at least one author from the regarded region and which comprise a reference list of cited documents.

As a first step, with BibTechMon a map of all selected publications is drawn based on similarity, whereby two publications are assumed to be more similar, if they have more common references. This reveals agglomerations of relatively similar publications. As the measure of similarity, the Jaccard-Index is used, which transforms the number of common references in relation to all references of a pair of publications to a range from 0 to 1 (Rip and Courtial 1984).

Then, a map of agglomerations of similar publications is drawn as a 3D surface map of the weighted local density of the number of publications, measured by the Jaccard-Index of links. Peaks in this landscape are made up of publications that are highly similar due to a relative high number of common references. By manual selection with graphical assistance, a core set of publications is selected from the peak. From this core set, publications above a threshold of common references are used to define a so-called “Research Field”. In this way, region-specific Research Fields are defined by co-citation analysis (bibliographic coupling, see, for instance, Boyack & Klavans 2010) are defined, to describe the scientific activity in the region.

To grasp the scientific content of a such a structurally defined Research Field and to assign suitable labels to it, a specific bibliometric methodology was applied. It combines bibliometric indicators on most relevant keywords, titles, abstracts, and cited references of the publications with expert judgement. The abstracts of the highest cited publications of the reference list of all references in the Research Field were read, the most relevant keywords ranked by the TFIDF (text frequency inverse document frequency, see Roche et al. 2010) were taken into account to name the Research Field.

Summing up, the complete research activity in the defined region and time period was visualized in the publication landscape. Research activities based on similar citations appear as peaks in the landscape of publications, representing the thematic areas of the publication activity in the region.

Key digitalisation topics and actors

The thematic focus of a territory was characterized by the set of Research Fields (as identified in the publication landscapes) from a territory with the highest number of publications. This added a qualitative dimension to the characterization of the core scientific activities in the territory, taking into account the authors´ own interpretations (keywords, titles and abstracts), and provides more descriptive, accurate and timely insights into the scientific work that is actually being done, than it would be possible through the use of pre-defined science categories.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement nº 873010.

Research fields were examined whether they contribute to the digitalisation issue. The relevance for digitalisation was calculated by the co-occurrence of Research Fields with disciplines that are highly relevant. A Research Field was defined as relevant for digitalisation if the sum of publications of disciplines which were defined as highly relevant for digitalisation was at least one.

We define key actors regarding scientific publication as organizations with the highest number of publications. However, since the affiliation of authors usually is not standardized in publication databases, it is very difficult to identify such key actors at organization level. We tried to approximate a valid assessment by using the newly available field, “Organizations Enhanced” in the WoS database, with substantially higher standardization level[4] of the organization names. The retrieved list of organizations was sorted, and, starting from the actors with the highest number of publications, the geographical assignment was established by manual desk research. The result is a list of the tentative Top 10 list of publication actors for each territory. It has to be conceded that, due to the mentioned standardization problems, caveats remain regarding these lists of key actors.

2.3.2 Social Network Analysis

Access to external knowledge and capabilities can be proxied by data on project-based, pre-competitive research networks, like those funded by the European Union in its Framework Programmes. The most important database in this respect is the RISIS-EUPRO database maintained by AIT, which allows to analyse region-internal and European-wide knowledge networks at the interface of basic research and industrial application (https://rcf.risis2.eu/dataset/4/metadata; for works based thereupon see, e.g., Scherngell 2013). Complementing local knowledge networks within the territories, additional data sources are tapped in the regions provided by regional funding agencies, cluster organizations and other intermediary stakeholders (Grand E-Nov, FFG, and Region Värmland).

The Social Network Analysis (SNA) perspective views the set of collaborative R&D projects as a collection of organisations (nodes in the network) that are connected by project collaboration (edges). By this we can infer on the structure of the social infrastructure for knowledge exchange in the R&I ecosystem, and on the role and positioning of individual organisations (e.g. who are key players in certain topics).

[4] The field “Organizations Enhanced” contains organization names which have been standardized partly, however, due to lack of additional information, there are still instances where a disambiguation of institutional levels or a territorial assignment is not possible.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement nº 873010.

The analysis is based on collaborative R&D projects in the Horizon 2020 Programme of the European Union (H2020 Programme), with participating organizations from the selected territory (2014-2020). The data is extracted from the EUPRO database, a comprehensive data resource of all EU Framework Programmes and of publicly funded national research programmes in a growing set of countries. EUPRO is a significant asset of AIT used for research projects and contract research for national and international customers, such as the European Commission (Heller-Schuh et al. 2011). It is part of the European Research Infrastructure RISIS (https://risis.eu/) and facilitates the analysis of participation patterns of organisations in different priorities of the FP and the investigation of collaborative network structures, including their evolution over time and the development of the European Research Area.

EU-Horizon 2020 collaboration

All projects from H2020 (2014-2020, Status March 2020) with participants from each territory, Grand Est, Styria and Värmland were retrieved from the EUPRO database. An illustration of the complete data retrieval and analysis procedure is given in Figure 2. For the delineation of the territories, postcodes of the organizations and NUTS codes were used (see Table 28 in the Annex). The digitalisation relevant projects were filtered out in a multi-stage process using keywords.

- Stage 1 was a pre-filtering process using the text strings '"*digital*" OR "*digiti*"' in the project title, project objectives and the field "TopicNames", which contains several standardized technical keywords related with the project. This step results in a preliminary list of projects for each territory.
- Stage 2 was the use of all "TopicNames" found in the previous step (a large number of technical keywords related to digitalisation). This list was then separated in two disjoint sets of keywords, one related to "development of digital technologies", the other related to "application of digital technologies". This assignment was done by expert judgment, and the resulting keyword sets are shown in Table 36 and Table 37 in the Annex.
- Stage 3 was then to use the development- and the application-keywords separately to retrieve the final sets of digitalisation projects with development aspects and with application-aspects from the EUPRO database for each territory.

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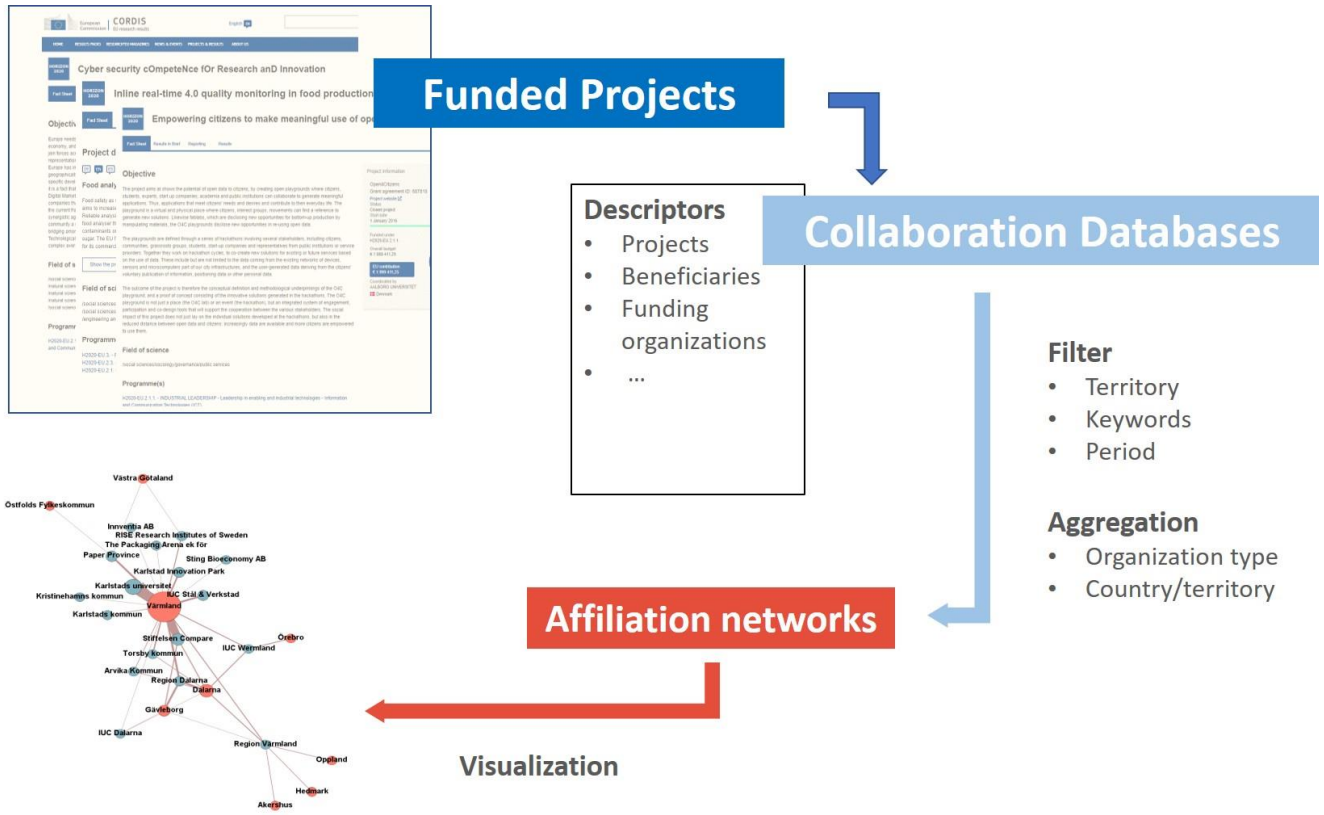

Figure 2. Procedure for network analysis of project collaboration in DigiTeRRI

The result of this search process is to have two (partly overlapping but not at all identical) sets of projects for each territory: “development-oriented” and “application-oriented” H2020 projects with participation from the territory, with all (international) partner and project information available in the EUPRO.

With this information at hand, networks were calculated using network analysis and visualization tools (Pajek[5] and Gephi[6]) to construct two organization networks for each territory, related with development and with application of digital technologies. Hereby, the network graphics were simplified by aggregating the organizations by organization type and country, while the territories were kept separately visible. The result is a kind of ego-network that is able to show the embedding of the territory within a European and – in some cases - global network of knowledge exchange.

[5] http://mrvar.fdv.uni-lj.si/pajek/
[6] https://gephi.org/

National/regional-level R&I projects

A second type of network is calculated and visualized using data from the regional level on R&I activities in the territories. Such networks usually have a stronger regional focus. In this case we calculate similar organization networks, using data from national authorities.

2.3.3 Patent analysis

Technological knowledge is often codified in patents, to protect inventions and technology development for a limited period. Inventors are granted a time-limited property right for the exclusive use of their invention. In return, they undertake to make the knowledge contained in their inventions public so that others can build on it. This individual exploitation incentive for the inventor and the general diffusion of the knowledge generated justify the patent's claim to drive innovation. That is why patent statistics are also considered to be essential indicators of the innovative strength of economies and are widely used in innovation research as empirical window to the knowledge economy (see Griliches 1990 for details on patent indicators).

However, sceptical voices refer to the changing framework conditions – globalization, digitalisation, virtualization of economies, open innovation – which question the efficiency of the established patent system. Typically, patents are widely used in innovation research since they represent industrially relevant knowledge typically in manufacturing industries (Powell & Giannella 2010), but also in ICT patent data are used to analyse technological profiles and inventor networks (Cecere et al. 2014), although for instance, software products – a core ingredient of digitalisation processes – are usually not patented. This caveat applies to all territories in the same way, that is why we nevertheless include patents in our study, keeping in mind that they should not be used as the only innovation indicator because they are not able to cover the full breadth of digitalisation.

The Patent Cooperation Treaty (PCT) assists applicants in seeking patent protection internationally for their inventions, helps patent offices with their patent granting decisions, and facilitates public access to a wealth of technical information relating to those inventions. By filing an international patent application under the PCT, applicants can simultaneously seek protection for an invention in a large number of countries. Such patents are usually seen as related with important inventions which have large exploitation potential. Regionalised information on PCT patent in this study come from the PATSTAT database, containing the geographical information of the organisations (mostly firms) inventing a patent, but also a detailed breakdown of technological fields which opens up a whole range of possible analytical applications.

Different criteria can be applied to count patents in terms of their geographical assignment: based on the (i) inventor's location or (ii) institution's location. Following the first criterion, the patent application is assigned

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according to the address of the inventor. This allows an interpretation of the regional potential for technological knowledge creation within the territory. We use the second criterion, i.e., patent applications are allocated to the region/territory of the applicant organization, which would more point to a territory´s commercialisation potential. However, patent applications are often filed through the headquarters and, hence, a headquarters bias may arise by overestimating the patenting activities in favour of the region of the headquarters. This is an important caveat in interpreting the current patent analysis for the territories. The choice taken to look at application addresses instead of inventor addresses may lead to an headquarter bias, i.e., the results may underestimate the technological capacities of the territory if firms apply for their patents through the headquarters outside the territory.

Delimitation of digitalisation patents

In the delimitation of digitalisation patents, we follow the standard OECD classification that assigns patents to ICT technological fields based on the International Patent Classification (IPC) system (OECD 2008). The OECD classification distinguishes the ICT sector in four subclasses; these are Computers and Office Machinery, Consumer Electronics, Telecommunications and Other ICT.

Specialization patterns

The patent data for the territories are analysed with simple descriptive statistics. Moreover, specialization patterns of the territories are assessed by means of the Revealed Technological Advantage (RTA), which is a specialization index often used to determine the relative thematic specialization of a given country or region in selected technological fields, based on patent applications. The RTA index is formally defined as follows.

$$RTA_{ik} = \frac{\frac{p_{ik}}{\sum_{i=1}^{n} p_{ik}}}{\frac{\sum_{k=1}^{m} p_{ik}}{\sum_{i=1}^{n}\sum_{k=1}^{m} p_{ik}}}$$

where p is the number of patent applications, i denotes the region with i = 1,…,n and k represents the technological field (IPC patent class) with k = 1,…,m. (p_{ik} denotes the number of patent applications in region i and technological field k).

In other words, in our case the RTA relates the share of ICT patents in a territory (Grand Est, Styria or Värmland) within all patents in the territory to the share of ICT patents in Europe within all patents in Europe. An RTA value lower than 1 indicates that the region is less specialized in the field than EU countries do on average. In contrast,

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an RTA value higher than 1 indicates that the region specializes more in the particular field than EU countries do on average.

CHAPTER 3: THE DIGITERRI R&I ECOSYSTEM IN GRAND EST

This Chapter presents the mapping of the R&I ecosystem in Grand Est with a special emphasis on digitalisation activities. The territory was selected as an example of a traditionally strong industrial region with classical industries like mechanical engineering, especially automotive, rolling stock and aerospace supply, with an acknowledged need to catch up in the digital transformation process. According to the mapping methodology (see Chapter 2 for details), the mapping results are structured in the same way for all three involved territories ensuring comparability despite large differences in terms of size, concrete industrial and technological structure and governance.

First, in Section 3.1 a brief account of the socio-economic profile of the region is given, covering the aspects industry structure, employment, education and figures on R&I activities. Section 3.2 sketches the institutional setup of the R&I activities, the related governance structures and the government strategies, including digitalisation and RRI. Section 3.3 describes digitalisation relevant R&I activities applying descriptive statistical and network analysis methods. It focuses on the creation of scientific knowledge, on knowledge exchange in collaborative research, and finally on technology development aspects.

3.1 Socio-economic profile

Région Grand Est is a large administrative region in Eastern France with 5.5 million inhabitants (representing 8.3% of the total French population in 2018). The regional capital is Strasbourg, which is given European-wide political importance hosting the seat of the European Parliament and the Council of Europe (including the European Court for Human Rights and the European Pharmacopoeia Commission). Since 2015, Grand Est supersedes the former administrative regions Alsace, Champagne-Ardenne and Lorraine. It has domestic borders with Région Ile de France (Paris), Bourgogne Franche-Comté (Dijon) and Haut-de-France (Lille). And it is characterized by its European openness: foreign borders are with four countries, Belgium (Wallonia), Luxembourg, Germany (Baden-Württemberg, Saarland and Rheinland-Pfalz) and Switzerland (Basel area).

The main metropolitan areas in Grand Est are Strasbourg (with a population of 491.000), Reims (295,000), Mulhouse (273,000), Nancy (257,000), Metz (222,000) and Troyes (170,000), jointly representing one third of the

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total population. Spanning an area of 57,433 km², the population density (96 inhabitants per km²) is below the national average (121 inh/km²).

Grand-Est accounted for 6.7% of the national GDP in 2017. The average annual growth rate since 2015 was 0.59%, which is well below the national level of 1.39%. The GDP per capita expressed in purchasing power standard was €24,900, which is below the French national average (€30,600 in 2017).

3.1.1 Industrial structure

Grand-Est is amongst the most industrialised regions of France, with 19.6% from the industrial sector, compared to 14.2% at the national level. But overall industry in Grand Est is in decline, showing negative annual growth rates in employment (-0.3% on average) between 2014 and 2018[7]. Other sectors contributing to added value are commercial service sector (45.7%), non-profit services (25.7%), building industry (5.8%) and agriculture (3.3%).

Materials, mechanics, textile, chemistry, agri-food industry (including agriculture/viticulture) constitute the backbone of the regional industry. The materials and processes sector in Grand Est represents 15% of national production of materials and 18% of scientific jobs in France. At the same time, the digital transition presents a major challenge for this industry.

Grand Est is France's second-largest exporting region behind Ile-de-France, with 64.7bn EUR worth of products sold internationally in 2018, giving it a trade surplus of 5.6 billion EUR. Six sectors represent 78.5% of regional exports: Mechanical and electrical equipment; Transport equipment; Food processing; Chemical products, perfumes, and cosmetics; Metallurgy; Pharmaceutical products.

3.1.2 Employment

Grand-Est is the second strongest industrial French region in terms of employment (15.2% of the total regional employment), with the largest regional employer being PSA (Peugeot-Citroën-Opel group) with three main plants (foundry, engine and mechanical elements, final assembly).

[7] Source: Regional Innovation Monitor https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/grand-est Accessed 9 June 2020.

The employment rate in Grand Est is around 63% (2,244,000 active people - accounting for 8.2% of the national workforce) in 2016. 63% are employed in the private sector, 19% in the public sector, 10% are independent and self-employed persons (farmers, entrepreneurs etc.) while 8% of employees are working at transnational level. Employment across other sectors is dominated by the service sector, with 42.3% in commercial tertiary and 33.5% in non-profit tertiary, while 5.9% of employment go on construction industry and 2.8% on agriculture. In absolute employment numbers, the most important industries are the following:

- Food-processing (56,000)
- Metallurgy (53,600)
- Machinery and equipment (51,400)
- Chemicals and materials, health technologies and energy (33,900)
- Manufacture of transport equipment (32,900)
- Wood, paper and printing (25,200)

With regard to female employment in Région Grand Est, 19.9% of executives were women in 2014. The wage gap between men and women is 11.5%.

Employment in high technology sectors (high-technology manufacturing and knowledge-intensive high-technology services) was 67,600 persons in total, of which 19,200 were females, representing 28% of all employed in 2019, and shows a decreasing rate from 32% since 2015[8].

3.1.3 Education

Education indicators in general are slightly lower than the national average: in 2018, 37.9% of the 30-34-year olds obtained tertiary education levels, below the national level (46.2%) and European level (40.7%). In 2017, the Grand Est had 218,201 high school students, 38,571 apprentices and 209,313 students, with enrolment trends comparable to the national situation. Engineering training outside universities is much more critical than at the national level (25.6% of the national workforce). Conversely, engineering training in universities is lower (5.1% of the national workforce). Concerning apprenticeships, five training specialities account for 83% of all apprentices in the Grand Est region:

- Trade and management, accounting, secretarial work, commerce, transport (21%)
- Food processing, chemical processing, metallurgy, energy (20%)
- Mechanical, electrical, electronic (17%)

[8] Source: EUROSTAT

- Personal services, including accommodation and food (13%)
- Civil engineering, construction, wood (12%)

Regarding higher education in Grand Est, the total number of students in 2017 was around 206,000 students. This represents 8,1% of the French student population and 9,2% of the whole French student population in engineering schools. The region ranks 5th in France in terms of the number of students in all higher education courses combined.

The level of vocational training is high in Grand Est. With 36.6% of the population aged 30 to 34 years having achieved upper secondary and post-secondary non-tertiary education in vocational training, the region is well above the French national level (30.9%) in 2019. This difference is quite stable through the last 5 years. Regarding females, this share is lower in Grand Est (32.1%) – a similar situation that in all of France.

Comparing this with educational attainment at university-level, the situation is quite different in Grand Est. Among all 30- to 34-year-olds, 38.1% have achieved tertiary education (ISCED11-levels 5-8), which is significantly below the French level (47.5%) in 2019, whereby this gap has even somewhat widened since 2014. Tertiary education among females is higher than with males in Grand Est: 41.8% of the 30- to 34-year-old women have achieved tertiary education levels. However, as compared with all French women of this age, there is still a large gap: in France, 52.3% of the females have achieved tertiary education levels, whereby this gap has virtually doubled in the last 5 years.

3.1.4 Research and Innovation

In 2013, Grand Est spent 1.94bn EUR on research and development (R&D), accounting for 1.30% of its GDP, which was lower than the French average (2.24%). The share of business expenditure on research and development was 52.73%, again below the national level (64.59%). The government share of R&D was also lower than the national average (7.54% versus 13.06%). As a result, R&D expenditure is mostly led by the higher education sector which accounts for 39.74% of the total R&D expenditure, almost twice as much as the national level (20.88%).

The Regional Innovation Scoreboard (based on the Community Innovation Survey) is a regional extension of the European Innovation Scoreboard, assessing the innovation performance of European regions on a limited number of indicators. Recent results indicate that Grand Est is a strong innovator in the European context, but slightly below the French national level, and even falls back in the Regional Innovation Index from 2011 to 2019 (see Table 1).

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Table 1. Grand Est (FRF) in the Regional Innovation Scoreboard (2019)

INDICATOR	SCORE RELATIVE TO	
	FRANCE (=100)	EU (=100)
Regional Innovation Index 2011	*92.5*	*98.7*
Regional Innovation Index 2019	89.7	91.5
Tertiary education	78	92
Lifelong learning	91	159
International scientific co-publications	91	86
Most-cited scientific publications	97	96
R&D expenditures public sector	87	94
R&D expenditures business sector	67	69
Public-private co-publications	83	85
PCT patent applications	79	87
Trademark applications	80	52
Design applications	68	56
Employment in medium and high technology manufacturing / Knowledge intensive services	82	73

Source: Regional Innovation Scoreboard 2019. For details of the scoreboard methodology, see https://data.europa.eu/euodp/de/data/dataset/regional-innovation-scoreboard.

According to the Regional Innovation Scoreboard, Grand Est performs somewhat below the French average with respect to R&D, both in terms of input (expenditures of the public sector, but especially so in the business sector), and in terms of output (international scientific co-publications, most cited publications and public-private co-publications). Patents, trademarks and design applications are significantly below the French level, which is itself already low as compared with the European level. Employment in Grand Est in medium and high technology manufacturing or knowledge intensive services is also lower than on French and European average.

3.2 R&I governance, strategies and institutional setup

Grand Est is a regional authority, in the same way as local authorities (cities, metropolitan areas) and departments. In Grand Est, there are four levels of local authorities with specific competencies. Each region is administered by the **regional council** (the regional council draws up its rules of procedure which determine, in particular, the number, powers and mode of operation of the commissions), and the **regional economic, social**

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and environmental council, a non-elected body with consultative powers (CESER). In 2019, CESER published a report on innovation in Grand Est (see bibliography).

The competences of the region are mainly centred on: **Economic development, innovation, land use planning, transport, and training,** including the management of high schools. The different evolution of the French legislations reinforced the scope of their powers and regional coordination actions in terms of the support they provide in the fields of economic development and innovation. The regional council of Grand Est is the managing authority in charge of coordinating and facilitating the link between stakeholders of the innovation ecosystem[9]. The region is given the managing authority for the **European structural funds**. It includes some transregional programs as the INTERREG Upper Rhine space (Alsace, part Of Baden-Wurttemberg and 5 cantons from North-western Switzerland).

Alongside with the Regional Authority Grand Est, the **Chamber of Commerce and Industry of Grand Est** (CCI Grand Est) contributes to the governance of R&I activities, whereby CCI Grand Est is in charge of supporting the local businesses. The **Regional Delegations for Research and Technology** (DRRT) are the administrative missions in charge of the State's agendas in research, technology and innovation, the dissemination of a scientific and technical culture, and its interaction with the socio-economic world and the general public.

In 2018, the Region Grand Est and CCI Grand Est have jointly set up **Grand E-nov**, the regional innovation agency with the main objective to provide services to regional companies to foster innovation through supporting the innovation projects, accelerating start-ups, funding projects and supporting the implementation of complex territorial projects. The Euro metropolitan area of Strasbourg and the three metropolitan areas of Metz, Nancy and Reims also support economic development and innovation in their respective territories. The 2019 budget for the Grand Est Region, voted on 22 January 2019 is around 3.2 bn EUR. Innovation therefore represents 2.8% of this budget.

Since 2016, the Regions in France have been given responsibility for the **vocational training** of young people and job seekers, as well as for apprenticeship policies. The Region is responsible for the construction, maintenance, and operation of **general secondary schools, vocational secondary schools and agricultural schools**. Region Grand Est has to establish **regional strategies for higher education, research and**

[9] https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/grand-est°

innovation (SRESRI) to better coordinate their actions in the territories and to link up closely with the strategy for economic development (SRDE-II) and spatial planning (SRADDET).

The region has established several strategies related to its competences: economic development, youth, high school, international and cross-border relations, transport and travel, commitment and citizenship, innovation, higher education and research, environment, spatial planning, tourism, culture, sport, vocational training, agriculture and forestry. In this Subsection, we quote the most relevant for digitalisation.

3.2.1 Economic development

The Regional Economic Development, Innovation and Internationalisation Scheme (SRDE-II) defines the guidelines for aid to businesses, support for internationalization, assistance for property investment and business innovation. The SRDE-II defines orientations in terms of the attractiveness of the regional territory and development of the solidarity economy. The Region alone is competent to define aid and general aid schemes (grants, loans, repayable advances, etc.) for the creation or extension of economic activities or firms in difficulty.

Regional Plan for Economic Development, Innovation and Internationalization (Be EST)

Be EST is the most important strategy in the region and provides a set of ambitious and adapted tools at the service of companies to make the economy of the Greater East a proactive, innovative economy, ready to take up and anticipate the new challenges of the 4th industrial revolution. It is the blueprint that provides the regional line for innovation. It built around 6 Objectives, 7 strategic orientations and 26 priority actions. The 7 orientations are divided as follows: "Industry of the future", "Innovation", "International growth", "Attractiveness", "Territorial synergies", "Effectiveness of public action", "Financial engineering". The most important priority actions are:

- Boost innovation and economic transition towards the industry 4.0 economy, to become a European leader for Factories of the Future and the bioeconomy sector;
- Foster innovation by pooling several related mechanisms: increasing private investments in R&D, increasing collaboration between private companies, public institutions and users and increasing the number of start-ups;
- Help SMEs grow internationally by supporting company export strategies;
- Boost cross border economic relations to increase the territorial attractiveness and bring in more FDI;
- Ensure that innovation occurs throughout the territory by enabling territorial synergies, notably between rural and urban areas;

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- Reinforce the region's role as an innovation leader, to structure networks and increase public involvement in innovation;
- Create innovative funding solutions to assist the development of SMEs[10].

An **SRDE-II** oriented towards innovation focuses on sectors or fields with high innovation potential, such as the industry of the future or the bio-economy (Orientation 1), and in the desire to increase private investment in R&D and innovation, in particular by developing links between the various players but also by increasing the number of start-ups (Orientation 2).

This regional plan is also linked to the Smart Specialisation Strategy that defined the use of a part of the regional European funds (2014-2020). In the following, main actors in Grand Est Region from economic development and innovation are described.

The areas of **smart specialization strategy** give the region a competitive advantage based on its features. The aim is also to avoid duplication and fragmentation of efforts between European regions. The 6 S3 sectors identified in the Greater East are:

- Materials, process and production technologies, linked to the industry of the future
- Agro-resources (Agro-food processes, winery, bio-refinery);
- Health (including biotechnologies, medical technologies and medical equipment, health materials and silver economy);
- Sustainable construction;
- Sustainable mobility, logistics and transportation (including aeronautics and the car industry) through the digitalisation of the sector;
- Sustainable water management

[10] https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/grand-est

3.2.2 Training and education

Schools and vocational training

One of the priorities of the Great Investment Plan 2018-2022 launched by the State concerns the development of skills to facilitate access to employment. In a five-year period, “Regional Skills Investment Pacts” are implemented by the National government in cooperation with the Regions. The Grand Est Region concluded with the State on January 7, 2019 a regional pact to intensify training and employment support for young people and low-skilled job seekers and allow the transformation of the vocational training system with a skills-based approach. An Orient’Est toolkit provides an overview of the actions available to secondary school, high school and CFA students on their guidance. A tool built in collaboration with the National Education and the 3 Academies of the Grand Est.

The 3 academies (Nancy-Metz, Strasbourg, Reims) and the Regional Directorate for Food, Agriculture and Forestry are fully associated with and support this project. 49 educational organizations bringing together 33,000 high school students experimented with replacing textbooks with digital tools and resources for students and teachers in schools and at home. After gradual deployment, in 2020 the project will be completed in 350 high schools in the region. Thus, the 192,000 high school students in the Grand Est will have a laptop computer which they will own at the end of their schooling[11].

Higher education sector

The Région Grand Est hosts five traditional universities (University of Strasbourg, University of Lorraine, University of Reims-Champagne-Ardenne, University of Haute-Alsace and University of Technology of Troyes) with more than 206,000 students (2017), gathering 8.1% of the French student population and 9.2% of the whole French student population in engineering schools. In the last couple of years, the higher education sector of Grand Est was restructured, creating **three Communities of Universities and Establishments (ComUE)**, gathering the activities of universities and higher education institutions.

The **University of Strasbourg** gathers the University of Strasbourg, the University of Upper Alsace, the National Institute of Applied Sciences (INSA) and Strasbourg’s National School for Water and Environmental Engineering

[11] Source: Grand Est (https://www.grandest.fr/competences/formation-professionnelle-2/

(ENGEES), Strasbourg Architecture School (ENSAS), and the National University Library). The ComUE has around 55,500 students and 4000 researchers in 105 laboratories. The main research areas are biology, biotechnology, chemistry, materials and space sciences. The University of Upper Alsace also has a strong research interest in social sciences with the Human sciences interuniversity pole. The university of Strasbourg has links with public research in France and is partnered with the following public research institutes: the National Centre for Scientific Research (Centre National pour la Recherche Scientifique – CNRS), the National Institute of Health and Medical Research (Institut National de la Santé et de la Recherche Médicale – INSERM) and the National Institute on Agronomic Research (Institut National de la Recherche Agronomique – INRA).

The **University of Lorraine** brings together some 49 institutes, in 13 cities, organised around eight groups of disciplines. In 2018, 60,000 students were registered, and the university had 1809 PhD students working within 60 laboratories. The University funds research in sciences (agronomy, mathematics and ICT, biology, health and medicine, chemistry and molecular physics, mechanics, materials and environment) as well as in social sciences (language and communication studies, political sciences, law and management, as well as literature)[12].

The **University of Reims-Champagne-Ardenne** gathers some 32,000 students and is located on five distinct sites (Reims, Châlons-en-Champagne, Charleville-Mézières, Chaumont and Troyes). The ComUE is home to 1600 researchers. It has designated five research centres and affiliated technology platforms: Maison de la simulation (intensive calculations), the CERFE (ethology), PLANET (molecular chemistry and materials), NUM3D (3D digitalisation and prototyping), Nano'Mat (Nanomaterials)[13].

3.2.3 Research and Innovation

Public sector R&I

National R&I organisations present in Grand Est involve INRIA (French National Research Centre on Artificial Intelligence), CNRS, INSERM (Health, Biotechnologies) and the National Research Centre on Nuclear and Renewable Energies (CEA).

[12] Source: University of Lorraine, 2018
[13] Source: Université de Champagne, 2018

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Research commercialisation in Grand-Est is carried out by a SATT (Technology transfer organisation), a public institution that is supported by public research stakeholders and local entrepreneurs to facilitate technology transfer activities based on publicly funded research.

Industrial R&I

Regional innovation monitor plus: https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/grand-est

Competitiveness clusters were created in 2004 as part of a new industrial policy in France. Competitiveness clusters are groups of small, medium and large companies, research laboratories and training institutions. They are located in well-identified areas and focus on specific themes, working in conjunction with national, regional and local authorities. Today, six competitiveness clusters are active in Région Grand Est and are focused on materials and processes (Matéralia), health and medtechs (Biovalley France), Construction (Fibres-Energivie), water (HYDREOS), mobility (PVF) and bio-resources (IAR). They are based on a triple helix structure combining enterprises, RTD performers and TTOs and regional stakeholders. Most of the them have contacts and collaboration at international levels in trans-regional areas (Upper-Rhine, Grande Région - Saarland, Luxembourg, Belgium - Germany, Spain etc.). Grand Est also runs a network of regional clusters focused on textile (Pôle Textile Alsace) and agri-food (ARIA), ICT with Rhénatic, housing with PLAB, aeronautic with Aériades as well as media and digitalisation with Cinestic.

- The six competitiveness clusters
- The regional clusters
- SATT is a public institution that is supported by public research stakeholders and local entrepreneurs to facilitate technology transfer activities based on publicly funded research: SATT Conectus Alsace, SATT Grand Est, and SATT Nord;
- Twelve Regional Technology Transfer centres (CRITT) whom role is to facilitate collaborations and synergies between companies and to increase their technological level
- The Institute of Technology on materials and processes M2P, offering a development and research programme on materials, metallurgy and related processes;
- Regional incubators (SEMIA and Incubateur Lorrain) and three regional Technopolis (“Technopole de l’Aube”, “Technopôle Henri Poincaré” and “Technopôle de Nancy Brabois”) that helps startups based on public and private research to grow;
- And the key institutions representing the national level: the State administration representing the Ministry in charge of research, higher education and innovation (DRRT), the State administration

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representing both the Ministry in charge of industry and the Ministry in charge of labour (DIRECCTE);

- The various universities of Grand-Est are innovation drivers in the region, they are connected with national public research centres and the SATT to help foster innovation in the region
- The bank of Investment (BPI) which supports innovation through grants, loans

3.2.4 Digitalisation strategies and status

The region also focused on the **impact of the digitalisation on the industry** and the regional council has set ambitious strategy and related support programs to facilitate and accelerate it. The Region has launched in 2017, a plan to detect and assist companies that would like to audit their activities impacted by the transition towards Industry 4.0. More than 500 companies mainly SMEs have been audited. The region has also launched support programs to foster investment (AMI Industry of the Future) or to strength relationships between traditional industries, digital industries and RTD performers (AMI Numérique) trough collaborative programs. Development or reinforcement of transregional cooperation on topics as artificial intelligence, materials and processes, e-health, energetic transition is also a key subject for the regional authorities.

National digitalisation strategy

The objectives of the Digital Agenda in France are:

- Development of high-speed broadband
- R&I support on internet of the things, robotics and additive manufacturing
- Digital and energy efficiency
- Digital and mobility
- Human resources and digital transformation
- New business models induced by digital transformation

These objectives are implemented through specific support programs. In this document, we will summarize the most important ones:

French Tech is an accreditation awarded to French cities recognized for their digital ecosystem. It is also a name used by technologically innovative French businesses throughout the world. Convinced by the necessity to promote the emergence of successful start-ups and acceleration of the business of digital SMEs in France to

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generate economic value and jobs, the French Government created the French Tech Initiative at the end of 2013. Its philosophy: build on member initiatives of the French Tech themselves, highlight what already exists, and create a snowball effect. It is a shared ambition, propelled by the State but carried and built with all the actors of the French tech and start-up scene. The French Tech initiative also has a transversal objective: to enhance the coherence of public actions in favour of start-ups. It does not create a new organization or a new public tool, but is carried by a small team, Mission French Tech, which works closely with the French Ministry of Economy and Finance, the Ministry of Foreign Affairs and with the General Commissariat for Investment. Its partners, the pillars of the initiative, are national operators, who, under the common banner "French Tech" coordinate their actions in favour of start-ups: Caisse des Dépôts, Bpifrance (French Bank of Innovation) and Business France (support organisation to develop internationalisation of companies). Funding from the French Tech Initiative for accelerators (€ 200 million) and international attractiveness (€ 15 million) is part of the Investments for the Future program. In this context, the Bpifrance invest in companies (Deep Tech grants) accelerators and on Business France for international investments. The French Tech aims to provide a strong common visual identity to French startups and to promote entrepreneurial exchanges between them. One of the French Tech network is focused on IOT (Internet of the Things) and Factory of the future. In Grand Est, French Tech.

The **French Tech Tremplin program** is especially related to the topic of RRI. Its objective is to facilitate inclusion of entrepreneurs, which have not the network and the facilities of most favoured people. The program includes mentoring from successful entrepreneurs[14].

The Industry of the Future program was launched on 18 April 2015. Its goal is to modernize France's production tools and provide support for manufacturers as the digital changeover transforms their business models, organizations and the way they design and market their products. The New Industrial France programme is based on nine industrial solutions that provide real-world responses to key economic and social challenges: data economy, smart objects, digital trust, smart food production, new resources, sustainable cities, eco-mobility, medicine of the future, transport of tomorrow. Support initiatives were put in place in early May 2015 in each of France's regions, with the goal of providing customized modernization and transformation support to SMEs. 500 trained experts provided support to 3,400 SMEs throughout France in 2016, and the goal is to reach more than 4,000 such companies by the end of 2017.

[14] https://lafrenchtech.com/fr/la-france-aide-les-startups/tremplin/

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Alliance Industrie du Futur / Alliance of the industry of the future: The Industry of the Future Alliance is tasked with putting into practice the national Industry of the Future project launched by the French Government in April 2015, in the framework of the organisational overhaul of the New Face of Industry in France. Capitalising on the gains achieved in the "Factory of the Future" plan, this project is designed to play a central role in the New Face of Industry in France program, with a broader ambition now encompassing industrial modernization and the use of digital technologies, reinforced means of assistance, a stronger international dimension and a system of governance that brings together the industrial stakeholders at national and regional levels. The Alliance has a particular mandate to support companies in the transformation of their business models, their organisation, and their design and marketing methods, in a world in which new tools based, for example, on the digital, on additive manufacturing, on new materials and on advanced robotics are bringing down the barriers between industry and services.

PIA: French national investment plan – Calls for proposals are launched to fund mostly collaborative projects. Some specific calls are focused on Industry of the future. As digital is closely linked to industry of the future, most of the funded projects involved ICT companies, users and academics.

Digital Inclusion: 20% of the French population do not use properly digital tools. The objective of the national is to increase digital autonomy of the population especially for all the contacts with the administration. It facilitates setting up and widespread of local initiatives managed by local authorities[15]. The French authorities have launched in 2019 a call for proposal open to local authorities and related partners (public and private companies, social workers etc.) to propose trough local initiatives to the citizens a digital pass. The digital pass allow to register to specific training sessions[16] .

Digital Infrastructures: The objective in the next years is to develop high speed internet broadband infrastructure to guaranty at least 8 Mbit/s (30 Mbit/s in 2022) and to develop 4G. Medium term objective to propose at national level a optical fibre telecom network in 2025[17].

[15] https://societenumerique.gouv.fr/plannational
[16] https://societenumerique.gouv.fr/pass-numerique/
[17] https://www.amenagement-numerique.gouv.fr/

Regional digitalisation strategy

The region has embraced the digitalisation of industry and the regional council has set out an ambitious strategy to support companies in the transition towards Industry 4.0. The region has also launched support programmes to foster investment (AMI Industry of the Future) or to strengthen relationships between traditional industries, digitalised industries and RTD performers (AMI Numérique) through collaborative programmes. Grand Est has also included the S3 strategy. Development or reinforcement of trans-regional cooperation on topics as artificial intelligence, materials and processes, e-health, energetic transition is also a key subject for the regional authorities. The region implemented also high-speed internet infrastructure. Education and training all along the life are also key topics to foster digitalisation of companies.

The Region Grand Est and the Chamber of Commerce and Industry of Grand Est have decided to join their efforts and set up Grand E-nov, the regional innovation agency with the main objective to provide services to regional companies to foster innovation in 2018. The Région Grand Est has signed a partnership with Syntec Numérique (National association of the digital industry) and the regional innovation agency, Grand E-nov to implement actions on the topic[18]. Since 2016, more than 600 companies were audited to access their digital maturity and identify actions to be implemented to integrate state of the art technologies adapted to the specific needs of the companies (objective to assist 1000 companies in three years). Grand E-nov as regional innovation agency has integrated competencies coming from the industry to provide assistance to the implementation of action plans. Specific funding programs dedicated to investment or collaborative projects between technology providers and companies from traditional industrial areas were set up since 2016[19].

Specific policy: Artificial intelligence. In 2019, the Région Grand Est has launched a regional action plan focused on artificial intelligence to:

- Boost competitiveness of enterprises using artificial intelligence
- Promote and sustain academic excellence on the topic and foster valorisation of research works
- Foster development of start-ups from the idea to the first million-euro turnover
- Develop education and training including through setting up of new diplomas and training centres

[18] https://www.grandest.fr/la-region-grand-est-sengage-pour-lemploi-avec-le-syntec-numerique/
[19] https://www.grandest.fr/wp-content/uploads/2020/02/ob-2020-deliberation.pdf

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- Guarantee that use of IA will be ethic and inclusive

This regional plan is open to international cooperation especially with partners coming from Germany, Switzerland, Belgium and Luxembourg.

The next step is to set up a virtual institute focused on digital that will integrate other topics as cybersecurity, HPC, IOT, Blockchain etc. Connection with other “transition” as the energetic and environmental one will be also a topic trough by example development of activities related to development of Green IT. The funding of the activities of the Institute will be a mix between public (regional, national and European programs) and private funding.

Chamber of Commerce (CCI) of Grand Est has increased its offer of solutions for digitalisation by launching an initiative to identify companies at the regional level that could offer solutions for digital and moreover industrial transformation. CCI has set up a “club” in order to federate these companies and increase their visibility. CCI has also set up a serious game dedicated to industrial companies to identify needs and related solutions proposed by members of the Club. This initiative has been identified as a best practice at national level.

Clusters Alsace Digital and Rhenatic: Industry Hacking camp: it is a HACKATHON (A hackathon also known as a hack day, hackfest or codefest - is an event in which computer programmers and others involved in software development and hardware development, including graphic designers, interface designers and project managers, collaborate intensively on software projects). The objective is, in 54 hours, to find innovative solutions to answer to industrials problematics.

4iTEC 4.0: This private innovation platform is an industrial initiative by large companies as PSA (Peugeot), CLEMESSY, ALSTOM, SEB and by SMEs (Papeteries Zuber-Rieder) with headquarters in the PSA factory (Mulhouse). The objective is to set up collaborative innovation projects (TRL5-7) dealing with industrial transformation (including digitalisation) and then to disseminate in other industrial sectors.

The **Tango & Scan Local initiative** (metropolitan area of Strasbourg) aims to support collaborative projects between creative industries and companies from traditional sectors. It lays a strong focus on projects proposed by SMEs and issues annual calls for proposals.

Internet Infrastructure - THD (Très Haut Débit). THD is the French Very High Speed plan, launched in spring 2013, aims to cover the entire territory in very high speed internet by 2023. The plan represents an investment of 20 bn EUR in ten years, shared between the State, local authorities and private operators. This project is supported (300 million EUR) by the European Investment Bank (Juncker plan).

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In Grand Est, the main urban areas (266 municipalities) benefit from private equity investment (about 5% of the Grand Est) and the less dense, peri-urban and rural sectors (i.e. 4,929 municipalities - 95%) are the subject of proactive public policies already implemented for several years on the territory: Rosace and Losange projects carried by the Region in partnership with 9 departments and Moselle Fiber, carried by a mixed syndicate and initiated by the Moselle Departmental Council. Local stakeholders are required to establish development strategies that are consistent with these digital infrastructure deployment policies. Altogether, the THD plan comprises 5,132 municipalities to be connected by 2023[20].

Lycée 4.0. An education and training program for digitalisation has been enrolled in all 353 high schools to prepare young people for the digital transformation. In 2017, 49 establishments bringing together 33,000 high school students, were the pioneers of this action and experienced the global digital offer that replaces textbooks. Much more than a digital book, a set of tools and resources have been made available to students and teachers in schools, at home or accessible on a laptop. At the start of the 2018 school year, in partnership with the academic authorities (the Rectorate and the DRAAF) and in close consultation with the parents' federations, lycée 4.0 entered a second phase with 62 new “4.0” establishments and 34,000 additional students involved. For the start of the 2019 school year, the Grand Est Region has made the choice, with the academic authorities to further commit to digital. Thus, 182 additional establishments are going digital, and joining the 111 establishments already engaged. The Grand Est region is the first region in France to have made this ambitious choice of educational digital technology in order to offer each high school student in the Grand Est modern working conditions, meeting today's educational challenges and helping to facilitate their professional integration. Each new pupil in a 4.0 class has a free computer, which he will own at the end of his schooling. 115,000 computers have been ordered in order to ensure equal opportunities at a time when the curricula are radically changed and the pupil will have to make his own choice of subjects[21].

3.2.5 RRI strategies and measures

The six key areas of RRI are gender equality, science literacy and education, public engagement, ethics, open access, and governance. Most of these aspects are covered implicitly by the R&I policy strategies and measures. Here, we only refer to explicit RRI-related strategies in Grand Est.

[20] https://www.grandest.fr/tres-haut-debit/
[21] https://www.grandest.fr/lycee4-0/

Plan for equality between women and men

The Grand Est Region is aware that equality between women and men is played out both at local and national level, has decided to make a full commitment to make Grand Est an exemplary territory in terms of equality. Since 2017, this commitment from the Grand Est Region has been translated into practice by several actions:

- The appointment of a regional adviser delegated to equality between women and men
- The signature of the European Charter for Equality of Women and Men in Local Life, promoted by the Council of European Municipalities and Regions
- The creation of a Regional Prize for equality and gender equality with the aim of promoting gender equality in access to jobs and combating the persistence of gender stereotypes. This prize recognizes 100 young people undergoing training in a sector where they are under-represented, by encouraging girls to move towards so-called male trades and boys towards so-called female trades.
- In 2019, the Grand Est Region decided to also promote on the Grand Est territory, 12 innovative initiatives in favour of gender equality carried by associations, sports clubs, businesses, local communities and training.
- The establishment of an Equality steering committee composed of regional elected representatives representing different political sensitivities, agents of the Region and qualified personalities, members of CESER, who work daily for the status of women and for greater equality between women and men.

In parallel with the presentation and adoption of its annual report on gender equality, the Regional Council adopted a multi-year action plan to make its commitments a reality. This action plan is divided into 5 axes:

- Axis 1 - Promote the culture of equality internally within the Grand Est community
- Axis 2 - Raising awareness among young people, in particular 15- to 29-year-olds who represent nearly one million inhabitants of the Region
- Axis 3 - Develop regional equality policies in the fields of economy, employment, training, sport and culture
- Axis 4 - Promote the Equality Charter and policies

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 873010.

- Axis 5 - Supporting actors and initiatives: being a leader in the development of networks and partnerships, promoting equality in the Grand Est[22]

Fab Labs and Maker Spaces

A Fab Lab (fabrication laboratory) is a small-scale workshop or service offering (personal) digital fabrication. Typically, it is equipped with an array of flexible computer-controlled tools with the aim to create and develop "almost anything". Several Fab Labs are developing in Grand Est, especially supported by university platforms open to companies, citizens, students and also citizens. Associations practicing open access are being set up in cities and rural areas. Finally, companies (Axon cable for example) are integrating a Fab Lab to complete the tools available to designers. Examples are Fablab / Makerspace d'AV Lab (Strasbourg), Graoulab "Le Fablab de Metz" (Metz), Technistub - Fablab & Makerspace (Mulhouse), and others.

3.3 R&I performance in digitalisation

The central part of the mapping of the DigiTeRRI R&I ecosystem in Grand Est is to characterize the region with respect to the involved R&I actors and their role in the digitalisation process. We hereby provide quantitative and qualitative analyses of the R&I activities, taking a comparative perspective on the three involved territories, Grand Est, Styria and Värmland. We point out that, due to substantial differences among the territories, a direct comparison of the results, especially a ranking, is often not useful. Nevertheless, we structured the results sections in the same way, so that parallels can be drawn for trans-territorial learning.

The next three sections cover a spectrum of digitalisation activities in Grand Est starting from i), scientific research to ii), more application-oriented aspects focusing on knowledge exchange between research and industry, and also take into account, iii), the development of new digital technology.

3.3.1 Creation of scientific knowledge

As described in Section 2.2.3, we use publication data from the Web of Science database to analyse the thematic research activities in the region Grand Est. The identification of a relevant number of scientific articles

[22] https://www.grandest.fr/legalite-femmes-hommes/

for each region and their analysis was based on the previous definition of a geographic range corresponding to the regarded region, a certain time period, and a relevant thematic focus. Further on we used the software BibTechMon for keyword extraction and for further analysis. Disciplines, authors, affiliations, keywords and references were extracted from the relevant fields of the database.

Geographic range: Relevant publications with at least one author's affiliation from the Grand Est region were downloaded.

Time period: Publications in the time range 1998-2020 were taken into account with a result of 7958 publications on August 17th, 2020.

Thematic focus: A first analysis was made on the basis of the "WoS Categories", a set of scientific disciplines that is provided to characterize all publications in the Web of Science. We listed the WoS Categories and their numbers of publications from the territory and selected *core digitalisation relevant disciplines* to define its thematic focus. For the later analysis of Research Fields no a priori thematic filter was applied.

Core digitalisation relevant disciplines

The WoS categories of allow a first overview on the disciplines of published articles with at least one author from the region. The thematic delimitation was based on Web of Science (WoS) Categories as relevant scientific disciplines. By expert judgement, a set of WoS Categories was selected for Grand Est as having a direct relevance for digitalisation. Thus, core digitalisation relevant disciplines were identified and listed in Table 2 with their numbers of publications. Automation and Control Systems, Computer Sciences, Telecommunications, Mathematical & Computational Biology, Robotics, Imaging Sciences, Remote Sensing, Neuroimaging, and Medical Informatics were picked for Grand Est as digitalisation-related disciplines.

Table 2. Scientific publications in digitalisation-related disciplines from Grand Est (2018-20)

SCIENTIFIC DISCIPLINE	NUMBER OF PUBLICATIONS
Automation & Control Systems	126
Computer Science, Information Systems	123
Computer Science, Artificial Intelligence	110
Computer Science, Interdisciplinary Applications	110
Computer Science, Theory & Methods	104
Telecommunications	44
Mathematical & Computational Biology	43

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SCIENTIFIC DISCIPLINE	NUMBER OF PUBLICATIONS
Robotics	32
Computer Science, Software Engineering	30
Imaging Science & Photographic Technology	28
Remote Sensing	23
Computer Science, Hardware & Architecture	21
Computer Science, Cybernetics	18
Neuroimaging	18
Medical Informatics	6

Source: Web of Science (WoS); data retrieved August 17th, 2020.
Notes: Science discipline relates to the WoS Category; publications can be assigned to more than one WoS Category, resulting in multiple counting.

Digitalisation in the science map of Grand Est

Figure 3 shows the network of all Grand Est WoS Categories, with embedded digitalisation relevant WoS Categories (blue nodes from Table 1). This co-discipline network shows research activities in medicine on the left side, biology, environmental sciences and ecology in the bottom, chemistry, mathematics and statistics in the middle, and physics, materials science and computer science on the right side up to the top of the network with robotics.

The computer sciences and others strictly related to digitalisation research are marked blue and are found in the top right part of the network reaching into the centre with interdisciplinary applications, and which are connected with the medicine part of the network through medical informatics and neuroimaging.

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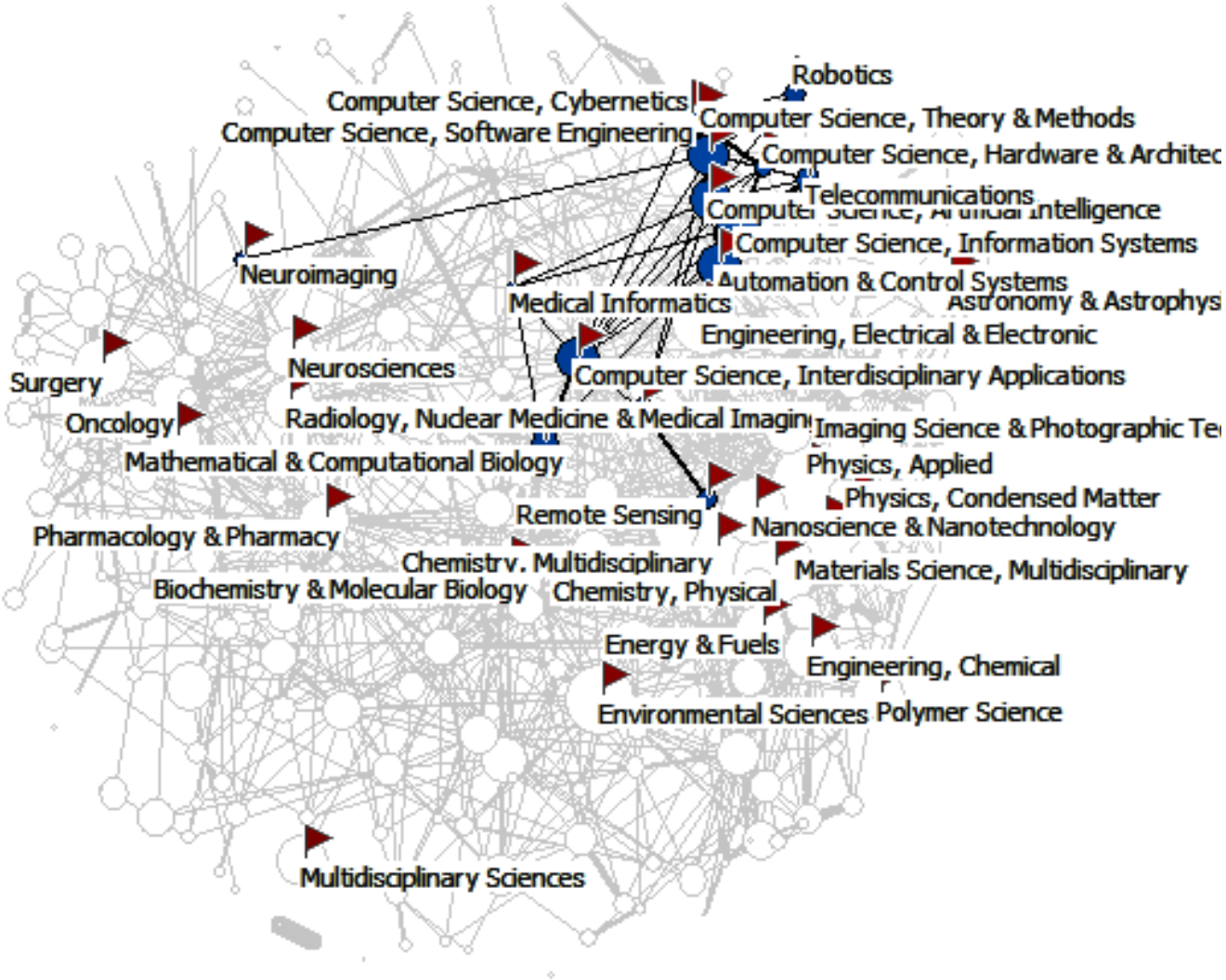

Figure 3. Co-occurrence network of scientific disciplines in publications from Grand Est (2018-20)

Source: Web of Science (WoS), data retrieved August 17th, 2020.
Nodes relate to WoS Categories; node size refers to the number of publications; edges relate to relative frequency of co-occurrence on publications (Jaccard-index). WoS Categories directly relevant for digitalisation are marked blue, with red flags and labels. White nodes with red flags mark disciplines with a number of publications 150 or higher, labels are shown for orientation reasons. WoS Categories with less than 25 publications are not displayed.

Publication landscape of Grand Est

As we intended to find clusters of publications that are related to digitalisation, clusters of similar publications were calculated which can be seen as research activities with a critical mass. We define *Research Fields (RF)* as such clusters of similar publications which we draw as a 3D surface map of the weighted local density of the

number of publications (using the Jaccard-Index of links). Hot zones around the peaks were made up of so-called core Research Fields documents that are highly similar due to a relative high number of common references. In this way created by co-citation analysis (bibliographic coupling) are giving a similarity-based proximity.

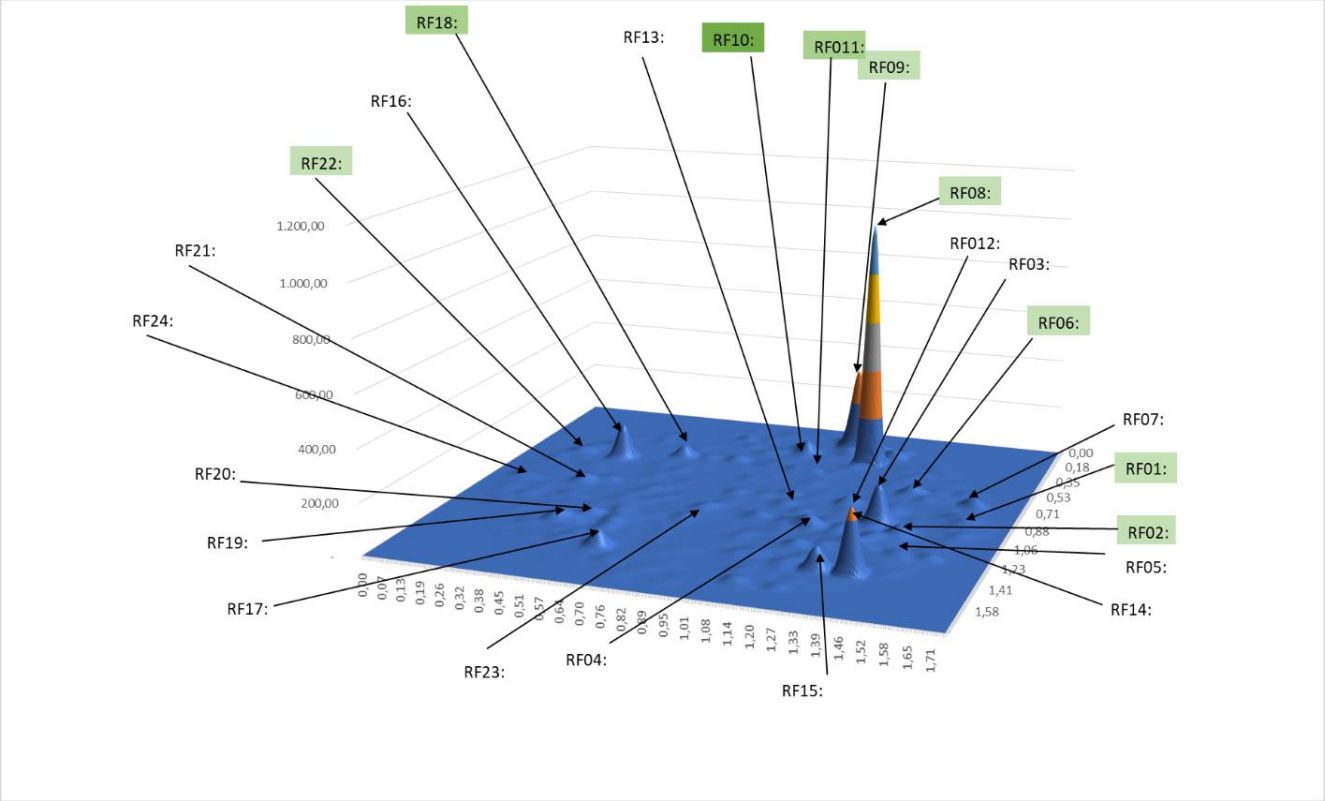

Figure 4. Landscape of publications from Grand Est (2018-20)

Source: Web of Science (WoS), data retrieved August 17th, 2020.
Note: Research fields in FRF: Map of the local density of similar (bibliographically coupled) publications. Fields with relevance for digitalisation are highlighted: light green: 1-5 publications, medium green: 5-10 and dark green 11-44, x-, y-axis: local coordinates, z-axis: number of publications weighted by the Jaccard-Index of similarity to other publications. For an explanation of labels see Table 3 and Table 30.

We mapped the complete research activity in the defined region and time period which is shown in Figure 4. Research activities are indicated with peaks in the landscape of publications. They correspond to the thematic areas of the overall research in the region. In this study we focused on research activities related to digitalisation which are indicated in green colour in the figure. The relevance for digitalisation was calculated by the co-occurrence of Research Fields with disciplines that are highly relevant for digitalisation, see Section 2.2.3 and

Table 11. A Research Field is defined as relevant for digitalisation if at least one publication was assigned to a digitalisation WoS Category.

Figure 4 shows the core Research Fields of the scientific landscape of Grand Est. The most significant peak comprises scientific publications on “Physics, Nuclear – ALICE, heavy ion experiments” with a high number of similar publications. The second highest peak refers to “Astronomy & Astrophysics – Gaia Data Release 2”. And the third one belongs to “Polymer Science - 3D printing, photopolymerization reactions”. Other significant peaks refer to: “Chemistry, Physical - porous adsorbens, density functional theory”, “Cardiac & Cardiovascular Systems - acute heart failure, drug treatment”, “: Chemistry, Physical - porous adsorbens, density functional theory”, and “Soil Science – agromining”.

Thematic focus Grand Est

Table 3 lists all Research Fields (detected peaks in Figure 4) which were found in direct relevance for digitalisation and their number of publications in WoS Categories which were previously defined as highly relevant for digitalisation. Main focus of the digitalisation literature of Grand Est was detected in the field of Automation & Control Systems with 44 relevant digitalisation publications. Also, Optics, Neuroscience, Physics, Materials Science, and Chemistry were found as digitalisation Research Fields of Grand Est.

Table 3. Digitalisation publications in Grand Est by Research Field (WoS 2018-20)

RESEARCH FIELD		NUMBER OF PUBLICATIONS
RF10	Automation & Control Systems – nonlinear networked control systems	44
RF11	Optics – photonic information processing	10
RF18	Neurosciences – rapid individual face perception	6
RF09	Astronomy & Astrophysics – Gaia Data Release 2	3
RF01	Materials Science, Multidisciplinary - Crystal	2
RF02	Chemistry, Multidisciplinary – Graphene, 2D materials, carbon nanomaterials	2
RF22	Surgery – hand surgery, scapholunate	2
RF06	Optics – light matter vibrational strong coupling	1
RF08	Physics, Nuclear – ALICE, heavy ion experiments	1

Source: Web of Science (WoS), data retrieved July 24th, 2020.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement nº 873010.

Key actors in scientific publication

Key actors in scientific publications were identified by repeating the WoS searches for each territory based on postal codes and by combining them with the WoS categories which were previously selected as directly relevant for digitalisation as described above.

The list of organizations of publication authors was retrieved from the WoS database by downloading the field "Organizations enhanced" together with the corresponding number of publications per organization. This field contain organization names which have been standardized already, however standardization is not complete yet. For instance, names of large organizations, such as CNRS can be found on different organizational levels, e.g. on organizational level and on institute level as well. In this way also organizations of co-authors are found inside these lists, not only those of the selected postal codes. Starting from the actors with the highest number of publications, it was then checked by desk research, whether the organization belongs to the desired region. A list of the Top 10 organizations was established for each territory. In some instances, large organizations such as the CNRS is listed several times, but the correct territorial assignment could not be clarified. In this case the list contains more than ten organization names.

Table 4. Key organizations from Grand Est in digitalisation-related scientific publication (2018-20)

ORGANIZATION NAME	NUMBER OF PUBLICATIONS
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	412
UNIVERSITE DE LORRAINE	395
UNIVERSITES DE STRASBOURG ETABLISSEMENTS ASSOCIES	107
UNIVERSITE DE STRASBOURG	94
CNRS INSTITUTE FOR ENGINEERING SYSTEMS SCIENCES INSIS	39
CNRS NATIONAL INSTITUTE FOR EARTH SCIENCES ASTRONOMY INSU	30
UNIVERSITE DE TECHNOLOGIE DE TROYES	21
CNRS INSTITUTE OF CHEMISTRY INC	20
CENTRALESUPELEC	19
CHU DE NANCY	18
UNIVERSITE DE HAUTE ALSACE UHA	18
INSTITUT NATIONAL DE LA SANTE ET DE LA RECHERCHE MEDICALE INSERM	17
INRAE	13
CHU STRASBOURG	10

Source: Web of Science (WoS), data retrieved September 9th, 2020.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 873010.

Table 4 gives the list of key actors in scientific publications. In Grand Est the universities dominate the scientific landscape. The French National Centre for Scientific Research (CNRS) is the leading public research organization and was listed here as two regional offices in Grand Est were identified (Centre Est and Alsace). The given publication numbers refer to total CNRS publications in the defined area, not only to the regional offices in Grand Est. Also, various CHUs (centre hospitalier universitaire) are highly represented. As well among the key players are the science and engineering school CentraleSupélec with its campus in Metz, the public scientific and technological institute INSERM with its regional site in Strasbourg which is dedicated to biomedical research and human health.

3.3.2 Collaborative research and knowledge exchange networks

To analyse knowledge exchange in the R&I ecosystem of Grand Est, we choose the European Framework Programme as the most important transnational R&D collaboration initiative, for mainly two reasons. First, because it has broad societal objectives and not merely an industry orientation, reflected e.g., in the “Societal Challenges”, and second, because it covers international knowledge exchange through the requirement to collaborate at a European level and moreover has the aspiration to links up with regional R&D. Thus, EU-projects can be used as a really good proxy indicator for knowledge exchange between cutting-edge development and application fields of digital technologies. The analysis of recent and currently running EU-funded projects related with digitalisation (see for details Section 2.3.2 for identification and filtering methodology) allows to characterize the institutional composition of the digitalisation R&I ecosystem in Grand Est.

In total, in Grand Est 74 organisations were and are active in altogether 121 projects in H2020 (2014 - March 2020). The largest share of actors in H2020 comes from industry (59% of the participants), which account for 44% of the project participations. However, it is important to note that universities and higher education organisations show a very strong position: with only 5% of the participants they account for 19% of all participations, while research organizations (11% of the participants) still represent 9% of the participations in digitalisation-related H2020 projects. Note, that since two or more organisations from Grand Est may be involved in the same project - which are counted as separate participations – so that the number of participations is slightly higher than the number of projects (129 participations from Grand Est in 121 H2020 projects).

Table 5. Institutional composition of Grand Est in H2020 digitalisation projects

ORGANIZATION TYPE	ACTORS		PARTICIPATIONS	
	NUMBER	SHARE	NUMBER	SHARE
Education (EDU)	4	5%	24	19%
Research organization (ROR)	8	11%	12	9%

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ORGANIZATION TYPE	ACTORS		PARTICIPATIONS	
	NUMBER	SHARE	NUMBER	SHARE
Industry (IND)	44	59%	57	44%
Other (OTH)	13	18%	31	24%
Government (GOV)	5	7%	5	4%
Total	74	100%	129	100%

Source: EUPRO (Status March 2020).

Thematic profile of Grand Est´s H2020 digitalisation activities

It is a buzzword today that digitalisation penetrates all economic and societal activities. To investigate how Grand Est´s digitalisation activities affect the different sectors of society and industry, we focus on the thematic profile of Grand Est´s involvement in H2020. Hereby, we look at the identified digitalisation project participations and their distribution over the H2020 subprogrammes. The most important subprogramme is “Industrial leadership”, gathering almost one third of Grand Est´s participations (see Table 6), which points at the strong the awareness of digitalisation with respect to global competitiveness. Furthermore, Grand Est is strongly represented in the other Thematic Programmes of H2020, above all in those on food security, health and transport, with 15%, 10% and 9% of the participations. The relevance for the whole society is also underlined by the fact that social sciences are strongly represented, with 7% of Grand Est´s participation in the programme “Science with and for society”, and the programme on inclusive, innovative and reflective societies with additional 3%. Climate, security and infrastructure topics follow up with 5% each of the participations.

Table 6. Grand Est´s digitalisation project participations in H2020 sub-programmes

SUBPROGRAMME	PARTICIPATIONS	
	NUMBER	SHARE
Industrial leadership	44	30%
Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy	23	15%
Health, demographic change and well-being	15	10%
Smart, green and integrated transport	14	9%
Science with and for society	10	7%
Climate action, environment, resource efficiency and raw materials	8	5%
Secure societies - Protecting freedom and security of Europe and its citizens	8	5%

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SUBPROGRAMME	PARTICIPATIONS	
	NUMBER	SHARE
Developing new world-class research infrastructures	7	5%
Innovation in SMEs	5	3%
Europe in a changing world - inclusive, innovative and reflective societies	5	3%
FET Future emerging technologies	4	3%
Secure, clean and efficient energy	3	2%
H2020-Euratom	3	2%
H2020 Total	149	100%

Source: EUPRO (Status March 2020).
Note: participations are subject to multiple counting due to joint calls of the H2020 subprogrammes.

Key players from Grand Est in H2020 digitalisation projects

To complement the sectoral distribution of Grand Est´s participation in H2020 digitalisation activities (Table 5), we now shed a light on the most frequent H2020 participants in the region (see Table 7). Here we find a strong concentration on a few research organizations, above all the University of Lorraine with a total of 15 participations, which alone represents 63% of all university participations from the region. The other top participants from the research sector are the Fondation Européenne de la Science, University of Strasbourg, Acteon and the Association des Agences de la Démocratie Locale.

In comparison, industrial firms are not as intensely involved in H2020 digitalisation projects. The top industrial player in terms of project participations is Soprema with 4 digitalisation projects. This reflects the fact that large multinational companies as contributors to basic technology development are absent, and the lead industry firms in the region are only selectively involved in digitalisation activities in H2020 – again an indication that the region is open for digital technologies but sees them merely as an enabler of their traditional activities.

Table 7. Top 10 participants from Grand Est in H2020 digitalisation projects

ORGANIZATION NAME	TYPE	NUMBER OF PARTICIPATIONS
UNIVERSITE DE LORRAINE	EDU	15
FONDATION EUROPEENNE DE LA SCIENCE	OTH	9
UNIVERSITE DE STRASBOURG	EDU	6
ACTEON SARL	OTH	4

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ORGANIZATION NAME	TYPE	NUMBER OF PARTICIPATIONS
ASSOCIATION DES AGENCES DE LA DEMOCRATIE LOCALE	OTH	4
SOPREMA	IND	4
ATRISC	IND	3
MATERALIA	OTH	3
TATA STEEL FRANCE RAIL SA	IND	3
ALERION	IND	2

Source: EUPRO (Status March 2020).

Grand Est´s digitalisation networks in EU-H2020

Due to the mentioned pervasiveness of digitalisation in the whole economy, but especially R&I activities, we use the distinction between two groups of R&I projects as an analytic device. First, we define “development-oriented” projects as related with the development of new digital technologies, methods and basic concepts at its core (like, for instance, data stream analysis), and second, “application-oriented” projects, which are such projects that are deeply rooted in application fields (e.g., like digital factories or rail operations). For this purpose we use specific thematic keywords that are available for each H2020 project, and group these keywords into two disjoint sets, namely development-oriented and application-oriented keywords (for the complete lists of keywords, see Table 36 and Table 37 in the Annex).

Filtering for these two sets of keywords, we obtain two (non-disjoint sets) of projects which have development or application aspects. The share of development-only digitalisation projects is 2%, while 71% are application-only projects. The large overlap of these two sets of projects (27% of the projects) highlights the fact that development and application are closely intertwined, again underlining the pivotal role of digitalisation in the broader R&I field.

H2020 development project network of Grand Est

In Grand Est, we identify a total of 35 development-oriented digitalisation projects in H2020 (29% of all Grand Est projects, which is a low share as compared with application-oriented projects), whereby partners from 38 countries are involved. Since we are interested in the knowledge exchange of Grand Est, we look at how participations from Grand Est are linked with other French and international partners in these projects applying network visualization techniques.

In the network diagram (Figure 5), the nodes represent participations according to their organization type and country, whereby participations from Grand Est are separated from the rest of France. Thus, for instance, a

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French university from Ile-de-France contributes to FR-EDU, a research organization from Sweden comes in as SE-ROR, while a Grand Est industry firm counts as FRF-IND. For greater clarity, the smallest nodes are cut off, i.e., the network diagram shows only nodes with participation numbers equal to 3 or higher, leading to a network with 65 nodes.

What we find in development-oriented digitalisation projects of Grand Est is a strongly industry-led network, with French firms (50 participations), together with German, Spanish and Italian industry firms forming the inner core of the network with highest participation numbers and dense networking, while all other organization types tend to be located more peripherally. This means that industry firms from these countries have more participations and more partnerships among themselves for potential knowledge exchange, whereas universities and research organizations – irrespective of their country affiliation – are less well-connected to these knowledge hubs as well as among their own peer group. Interesting to note is the fact that all development partners of Grand Est are European organizations.

Focusing on the organizations from Grand Est, industry (FRF-IND) is the strongest sector in the region both in terms of participations and connectedness; it is also quite close to the inner network core of the leading national industries, but also linked with German and smaller countries´ universities. Less closely connected to the core is the university sector of Grand Est (FRF-EDU), but it finds itself within a clearly identifiable university cluster, with UK, Italy, Spain, Greece and other countries. In comparison, research organizations and other organizations from Grand Est (FRF-ROR and FRF-OTH) are located on the periphery of the network, partly due to a small overall number of participations and also due to weak links to the industrial core of the development network.

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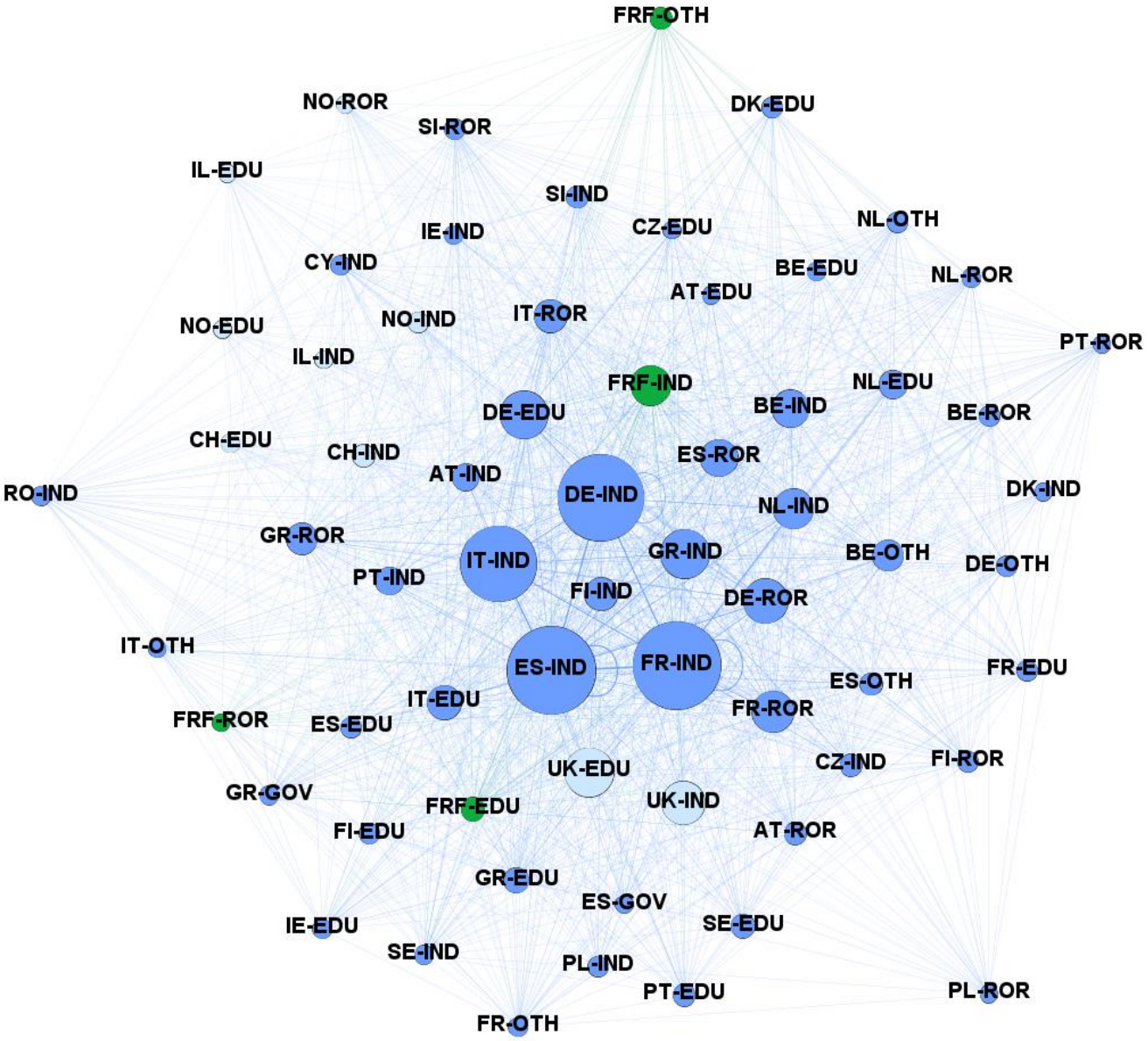

Figure 5. H2020 collaboration network of Grand Est in development-oriented digitalisation projects

Source: EUPRO (Status March 2020).

Note: Nodes refer to partner country and type of organizations, node size corresponds to the number of project participations from this group ($3 \leq n \leq n_{max} = 50$). Links refer to joint project participations, node distance corresponds to the relative frequency of joint project participations. Grand Est is distinguished (nodes in green and labels FRF-x) from the rest of France (labels FR-x). For organization type codes, country groups (colour of nodes) and country codes, see Table 34 and Table 35 in the Annex.

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H2020 application project network of Grand Est

In Grand Est, we find 119 application-oriented digitalisation projects in H2020, with partners from a total of 61 countries worldwide. This means that we have a much larger set of application-oriented projects than in development; in fact, no less than 98% of all Grand Est digitalisation projects exhibit aspects of application in an industrial or societal context. Comparing this with the development-oriented projects, it underlines once more the strong enabling role of digitalisation activities in Grand Est. To inquire the knowledge exchange potentials of Grand Est, we look at the collaboration network of Grand Est, i.e., how organizations are linked with other French and international partners in application-oriented projects. Applying network visualization techniques, we obtain the network diagram presented in Figure 6. Nodes stand for project participations from a certain organization type and country, whereby Grand Est is depicted separately from France, and nodes with less than 3 participations are cut off for greater clarity.

What we find is a much larger and more heterogeneous network with respect to country involvement. Almost all EU-28 countries plus Switzerland and Norway are involved in these Grand Est projects, and even other countries like Russia, Iceland and Israel. Again, it is an industry-led network, with French industry forming the center, and together with German, Spanish and Italian industry firms representing the inner network core. But unlike in development, research organizations and universities from Spain, Germany, France, and the UK are very closely linked to the leading industry club. Non-industry sectors, on the other hand, are typically located at the periphery of the network, indicating a mere sporadic involvement in Grand Est application projects.

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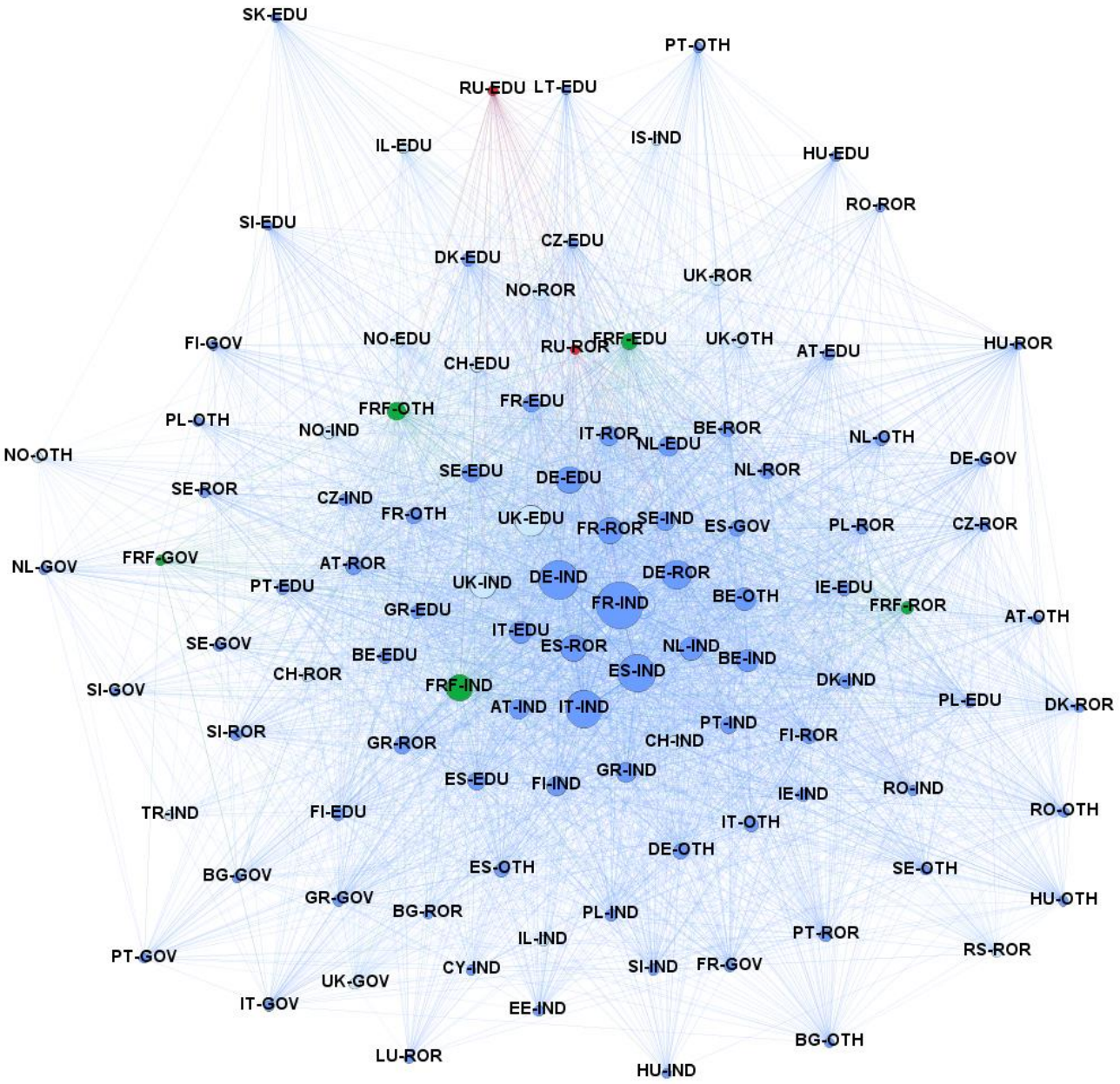

Figure 6. H2020 collaboration network of Grand Est in application-oriented digitalisation projects

Source: EUPRO (Status March 2020).

Note: Nodes refer to partner country and type of organizations, node size corresponds to the number of project participations from this group ($3 \leq n \leq n_{max} = 125$). Links refer to joint project participations, node distance corresponds to the relative frequency of joint project participations. Grand Est is distinguished (nodes in green and labels FRF-x) from the rest of France (labels FR-x). For organization type codes, country groups (colour of nodes) and country codes, see Table 34 and Table 35 in the Annex.

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Organizations from Grand Est are not deeply embedded in the very centre of the application network, with the only exception of the industry sector (FRF-IND), which is located quite close to the core but also within a group of European university and research organization sectors. The other sectors from Grand Est, universities (FRF-EDU), research organizations (FRF-ROR) and other organizations (FRF-OTH) seem to play the role of mediators between the network core and the peripheral participants from Europe and beyond.

Region-level digitalisation project networks in Grand Est

In the period 2014-20, one out of four thematic focuses of the European Regional Development Fund (ERDF) in France is to support the development of information and communication technologies (ICT). Under this frame, the region Grand Est has launched initiatives to strengthen relationships between traditional industries, digitalised industries and RTD performers (Appel à Manifestation d'Intérêt Économie Numérique - AMI Numérique). In the period 2017-2019, under AMI Numérique 101 digitalisation projects with partners from Grand Est have been funded, comprising a total set of 167 participating organizations. Collaboration in these innovation and investment projects is encouraged, but not a strict funding requirement, as it is the case under the EU Framework Programmes. Nevertheless, 73 of these projects are collaborative, i.e. have at least 2 project partners. Applying network visualization techniques leads to the network diagram shown in Figure 7.

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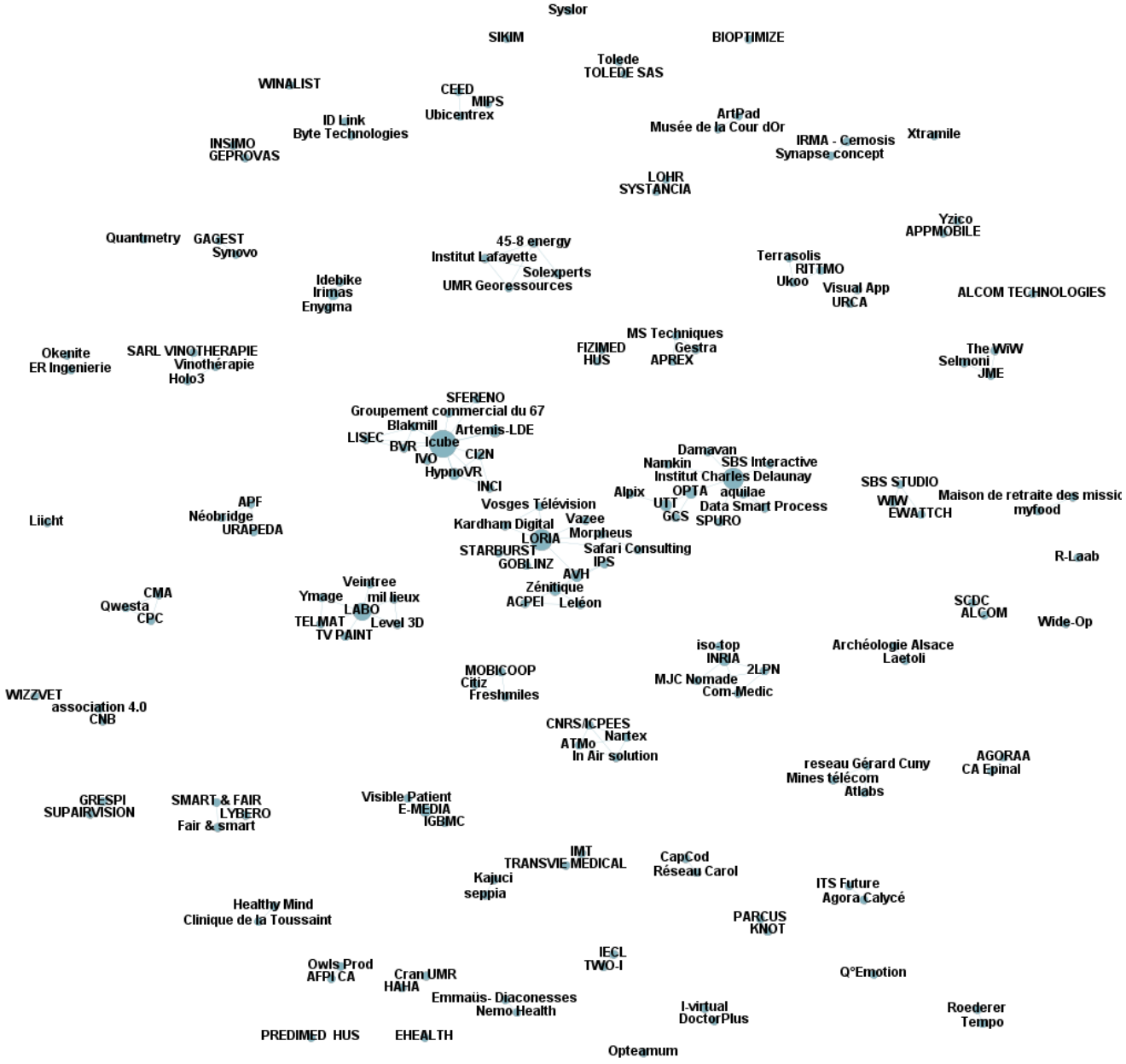

Figure 7. Collaboration network from AMI Numérique (ERDF) in Grand Est (2017-19)

Source: Grand E-Nov (Status August 2020)

Note: Nodes refer to participating organizations, node size corresponds to the number of project participations (n_{max} = 7). Links refer to joint project participations, node distance corresponds to the relative frequency of joint project participations. The position of unconnected clusters is arbitrary.

The network of beneficiaries receiving funding from AMI Numérique is a very fragmented one, i.e. it fails to integrate into a connected network of collaboration. The reason is that due to the program objectives and collaboration requirements therein, project consortia are very small on average (2.2 partners per project), and only a few organizations have more than one project partner. Clustering is present around the few organizations that participate in more and larger projects, as it is the case, for instance, with Icube (7 partners), Institut Charles Delaunay (5 partners), LORIA (5 partners) and LABO (4 partners). It should be noted that, this finding is not per se negative, but if knowledge exchange on a larger scale is an objective of the program, some additional measures to foster collaboration is definitely desirable.

3.3.3 Development and application of digital technologies

Patenting activities in a region allow for the analysis of the territorial R&I ecosystem from the perspective of technology development and its economic exploitation. Based on the International Patent Classification (IPC), we focus on those technology classes which are especially relevant for digitalisation – information and communication technologies (ICT) – using the standard OECD classification that assigns patent subclasses to so-called ICT fields (see Table 33). Since each patent is assigned to one or multiple patent classes, this kind of data is very well-suited to gain insights into the ICT-internal distribution of technologies, and their influence on non-ICT technologies, and thus the whole technological variety of the R&I ecosystem.

Patents in Information and Communication Technologies (ICT)

Retrieving PCT patents from the PATSTAT database with applicants from Grand Est (NUTS code FRF) in the period 2014-2018, we identify a total of 3,269 international patents of which 15% are assigned to at least one ICT field. This set of 503 ICT patents was selected for further analysis, whereby 332 Grand Est organizations are involved as applicants. The further analysis is based on fractional counting, i.e., in case a patent is assigned to more than one patent class, these patent classes receive respective shares of the patent count. Mutatis mutandis is applied to multiple applicants. In this way, we obtain weighted numbers for better comparison of the subsectors.

In total, Grand Est accounts for 219.7 ICT patents (fractional counting) in the period 2014-18, representing 11% of all patenting activity (2,000.8 patents) in Grand Est (Table 8). This is a low share as compared with the other two regions in DigiTeRRI, Styria in Austria and Värmland in Sweden. Within ICT fields, with almost two thirds of the patents (138.5), “Other ICT” is the most outstanding, representing various measurements and semiconductor technologies subclasses. “Computers, office machinery” accounts for 47.1 patents and 28.1 patents go on

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"Telecommunications". Less important for Grand Est is the field "Consumer electronics", comprising only 6 patents during the covered application period, representing 0.3% of all patents (Table 8).

Table 8. ICT patents from Grand Est by subclasses (2014-18)

ICT SUBCLASS	PATENTS		
	NUMBER	SHARE	RTA
Computers, office machinery	47.1	2.4%	0.36
Consumer electronics	6.0	0.3%	0.19
Other ICT	138.5	6.9%	0.75
Telecommunications	28.1	1.4%	0.19
Total ICT patents	219.7	11.0%	0.44
Total patents	2,000.8	100%	1

Source: PATSTAT;
Note: Calculations based on fractional counting

The Revealed Technological Advantage (RTA) is a well-established measure of technological specialization of a territorial unit; it can be measured in terms of patents (for details of the methodology see Section 2.3.3). The figures for the RTA[23] in Table 8 relate ICT patenting in Grand Est to the European level (EU28 plus Switzerland and Norway). The results show a remarkable underrepresentation of all ICT fields in Grand Est as compared with the European average. This weakness regarding the ICT specialization profile of Grand Est even includes its most prominent subfield of ICT, namely "Other ICT", which reaches only an RTA of 0.75 of the European level. Especially low is the RTA in "Consumer electronics" and "Telecommunications". It has to be noted that, - since France as a whole country shows an average specialization in ICT with regard to the European context – Grand Est also lags behind in ICT patenting within France. However, it has to be noted again that we may encounter a headquarter bias here, since for instance, the biggest ICT company having plants and research centres in Grand Est has its headquarters outside the Region. In such cases, inventions that emerge from Grand Est teams do not count for the localisation of the team but for the localisation of the top management.

[23] The RTA gives the relation between the share of ICT patents in Grand Est among all Grand Est patents and the share of European ICT patents among all European patents. Thus, an RTA value below 1 indicates a weaker representation of ICT patents in Grand Est than in Europe, whereas a value above 1 indicates a stronger ICT representation in Grand Est than the European average.

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Key patenting actors in ICT

Key actors in digitalisation-related patenting in Grand Est are led by companies, which is no surprise, since patents are generally considered as output of industrial innovation efforts, characterized by application oriented and exploitation-driven research, and serve as a main means of protecting a firm´s intellectual property. Here, measurement and process equipment (Endress+Hauser), chemicals (Merck, BASF) and data analytics (ROLIC) have to be mentioned. However, no less than 50% of the Top 10 ICT patent applicants are public research organizations (LIST, CNRS) or universities (Université de Strasbourg, Université de Lorraine, Université de Technologie de Troyes) (**Table 9**).

Table 9. Top 10 applicants for ICT patents in Grand Est (2014-18)

ORGANIZATION NAME	NUMBER OF PATENTS
Endress+Hauser Flowtec AG	29.0
Merck Patent GmbH	16.3
Luxembourg Institute of Science and Technology (LIST)	15.5
Endress+Hauser Process Solutions AG	15.2
Centre National de la Recherche Scientifique	13.3
ROLIC Technologies AG	13.0
BASF SE	12.0
Université de Strasbourg	12.0
Université de Lorraine	11.1
Université de Technologie de Troyes	10.5

Source: PATSTAT
Note: Calculations based on fractional counting

A striking observation is the broad distribution of patents across applicants: The listed Top 10 applicants comprise only 29% of all ICT patents in Grand Est. This is due to the fact that there is no large global industrial firm in ICT development, but ICT plays a generic role in a broad range of industries and in public sector and academic research.

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CHAPTER 4: THE DIGITERRI R&I ECOSYSTEM IN STYRIA

This Chapter presents the mapping of the R&I ecosystem in Styria with a special focus on digitalisation. The territory was chosen because it is, in its northern parts, a traditional resource-based industry region, with enduring difficulties in structural change, while in its central area, automotive industry and electronics industry such as semiconductors or electronic components have boosted economic development in the last few decades. Digitalisation is seen both a challenge and an opportunity to develop the region in a more balanced way. According to the mapping methodology (see Chapter 2 for details), the results for all three territories are structured in the same way ensuring comparability despite large differences in terms of size, concrete industrial and technological structure and governance.

First, in Section 4.1, a brief account of the socio-economic profile of the region is given, covering the aspects industry structure, employment, education and figures on R&I activities. Section 4.2 sketches the institutional setup of the R&I activities, the related governance structures and the government strategies, including digitalisation and RRI. Finally, Section 4.3 describes digitalisation relevant R&I activities applying descriptive statistical and network analysis methods. It focuses on the creation of scientific knowledge, on knowledge exchange in collaborative research, and finally on technology development aspects.

4.1 Socio-economic profile

Styria is a federal province (“Bundesland”) of Austria, located in the south of the country, with a population of 1.25 million in 2019, representing 14% of the Austrian population. Traditionally both a resource-based and industry-oriented territory, Styria has become a European-level high-technology region and hosts automotive industry and electronics industry such as semiconductors or electronic components around the provincial capital Graz (NUTS2 regions Oststeiermark, West- und Südsteiermark and Graz).

In 2017, regional GDP in Styria amounted to 47.2bn EUR, accounting for 12.8% of the Austrian GDP. Regional GDP grew by 2.29% between 2016 and 2017. Regional GDP per capita, reached 33,000 EUR in purchasing

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power standard (PPS), representing 91% of the Austrian average and 115% of the EU average[24]. Exports from Styria amounted to a total of 25.4bn EUR in 2018, Styria thus ranking second among provinces in Austria, and first in terms of export growth from 2017 (+17%). The top destination countries are Germany (6.5bn EUR), the US (2.4bn EUR), Italy (1.7bn EUR), the UK (1.2bn EUR) and China (1.0bn EUR), whereby the highest growth rates were with the US and the UK[25].

The economic situation is different in the northern part, Upper Styria (Obersteiermark), comprising the NUTS2 regions Liezen, Östliche Obersteiermark and Westliche Obersteiermark, and a total population of 339,000 in 2019. There, industry is traditionally dominated by iron ore mining and metallurgy of iron and steel in this mountainous region, especially in the Mur-Mürz valley. Enduringly, Upper Styria attempted to become an innovative region, however, with very view exceptions, the industry remained concentrated in improvement of steel products technologies. Today, many supplier or customer industries around the steel industry are settled in the area. The focus on material production attracted also other material producing segments such as polymer engineering, industrial logistics or environmental engineering. The crises in the last decade initiated a heavy loss of jobs in the region. This loss of jobs was an additional driver for the continuing domestic migration trend away from Upper Styria towards the neighbouring urban centres, especially with young people – a continuing trend.

4.1.1 Industrial structure

Styria is considered a robust economic player and an innovative, forward-looking area with the potential to anticipate and adapt to the changes caused by new trends such as digitalisation. With a research quota of more than 5%, Styria is a leader among Europe's research-oriented regions. Styria has set up a profound cluster and network strategy. One of the territory's strengths is its strong collaborative network among science, industry and public organisations, reflected for example by the fact that Styrian partners are involved in 25 of 42 Competence Centres for Excellent Technologies (COMET). Furthermore, serval universities are highly engaged in research projects promoting new technologies. All over Styria technology parks are situated to support innovative businesses with a common field of expertise not only with up-to-date infrastructure but also with extensive services. Universities and their start-up centres have promoted a lively entrepreneurial culture and a new orientation of technology in the territory.

[24] Source: EUROSTAT
[25] Source: Statistik Steiermark

Styria's economic sector has undergone significant structural changes over the past decades. Until the late 1980s, the iron and steel industry, as well as the automotive industry were the dominant economic branches. However, these sectors suffered from a dramatic decline during the 1990s. Only the latter sector (automotive suppliers) has recovered and regained international visibility. Major industries today include the automotive industry, mechanical engineering, electronics, and paper. Major multinational enterprises include Andritz AG, voestalpine Metal Engineering Division, and Magna Steyr Fahrzeugtechnik AG & Co.KG. Styria features an important automotive cluster, "ACstyria", which is located around Graz and incorporates more than 250 component suppliers, a central cluster actor being Magna. Recently, the Silicon Alps Cluster has begun its activities in Styria and its main focus is on technology and innovation for electronic-based systems. Other clusters include the sectors of wood, human technology, materials and food technology.

4.1.2 Employment

Total employment in Styria was 612,400 persons in 2019, representing a stable share of 14% of Austrian workforce over the last 5 years. In Styria, 46% of employed were women in 2019, this rate has been stable over the last 5 years. Employment in high technology sectors (high-technology manufacturing and knowledge-intensive high-technology services) was 21,100 persons in total, which represents 12,3% of all Austrian high-tech jobs – a slightly lower share than with total employment. In Styria, 6,100 employees in high tech were females, representing 29% of all employed in 2019, and shows an increased rate from 27% since 2015. In Upper Styria, the northern part of the region with the long tradition in iron and steel industries, there is a lower employment rate among women. In 2017, the general employment rate for women was around 40%, with less than 35% in industrial sectors. On the other hand, the rate of women engaged in technology-oriented studies is constantly rising[26].

4.1.3 Education

The level of vocational training is very high in Styria. With 44.3% of the population aged 30 to 34 years having achieved upper secondary and post-secondary non-tertiary education (levels 3 or 4) in vocational training, the region is well above the Austrian national level (39.3%) in 2019, which is itself a high value in international

[26] Source: EUROSTAT

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comparison. This difference has been quite stable during the last 5 years. Among women, the share of vocationally trained persons is slightly lower in Styria (42.5%) – but still far above the Austrian level (35.2%).

Comparing this with educational attainment at university-level, the situation is different in Styria: Among all 30- to 34-year-olds, 41.3% have achieved tertiary education (ISCED11-levels 5-8), which is below the Austrian national level (47.5%) in 2019. However, Styria has witnessed a fast catch up process since 2014: While Styria was behind the Austrian level by 4.8 percentage points, the difference has been reduced to 1.1 in 2019. Interestingly, this change is mainly due to female education achievements. Tertiary education among women is higher than with men in Styria: 46% of the 30- to 34-year-old women have achieved tertiary education levels, rising from 37.5% in 2014, so that Styria has surpassed the Austrian average of 45.6% in 2019[27].

4.1.4 Research and Innovation

Today Styria is seen as a robust economic and future oriented region, having sufficient potential to innovate and to react in advance to new trends such as digitalisation and implement its benefits, even if the qualification and need of employees will be different. The regional research quota is higher than 5%, positioning Styria in forefront of the research-oriented regions in Europe.

In 2017, Styria´s expenditures on R&D amounted to 2.3bn EUR (GERD, intramural R&D expenditure), representing 4.88% of the regional GDP - a quite substantially higher share as compared with 3.05% at the national Austrian level. Business expenditure in Styria was 1.7bn EUR in 2017, equalling a share of 74% of total R&D expenditure in Styria, and representing 3.6% of the regional GDP. Thus, in the performance of R&D the business sector is dominant and underlines the technological strength of Styria.

The Regional Innovation Scoreboard (RIS, based on the Community Innovation Survey) is a regional extension of the European innovation scoreboard, assessing the innovation performance of European regions on a limited number of indicators. The resolution of the RIS is not available at the level of Styria (AT22), so we have to rely on the figures for Southern Austria (Südösterreich, AT2), which is an aggregate of AT22 and the much smaller federal province of Carinthia (AT21). We therefore discuss briefly the results for AT2 as a viable proxy for Styria (Table 10).

[27] Source: EUROSTAT

Table 10. Südösterreich (AT2) in the Regional Innovation Scoreboard (2019)

INDICATOR	SCORE RELATIVE TO	
	AUSTRIA (=100)	EU (=100)
Regional Innovation Index 2011	*99.2*	*112.5*
Regional Innovation Index 2019	101.3	116.2
Tertiary education	85	88
Lifelong learning	91	135
International scientific co-publications	93	110
Most-cited scientific publications	85	82
R&D expenditures public sector	106	124
R&D expenditures business sector	130	169
Public-private co-publications	107	152
PCT patent applications	103	128
Trademark applications	81	129
Design applications	89	111
Employment in medium and high technology manufacturing / Knowledge intensive services	96	92

Source: Regional Innovation Scoreboard 2019. For details of the scoreboard methodology, see https://data.europa.eu/euodp/de/data/dataset/regional-innovation-scoreboard.

According to the Regional Innovation Scoreboard, Südösterreich (AT2) is a strong innovator in relation to the EU level and has increased its performance during the period 2011-2019. As such it has surpassed Austria´s overall performance level. Regarding R&D, the expenditures in the business sector are especially outstanding, amounting to a score of 130 as compared with Austria and 169 in relation to the EU. Scientific output, measured in terms of international co-publications and most-cited publications are lower than the Austrian average, but public-private co-publications are higher than in the whole country, even more so with respect to the EU-level. Some leeway seems to exist in employment in medium and high technology manufacturing as well as in knowledge-intensive services, where Südösterreich significantly lags behind Austrian and European levels.

4.2 R&I governance, strategies and institutional setup

Styria is one of nine federal states (Bundesländer) of the Republic of Austria. Despite a formally independent constitutional set-up, however, Austrian federal states are practically far less independent than, e.g., German federal states. In the field of R&I, three Austrian ministries play an important role at the regional level, the

Federal Ministry for Education, Science and Research (BMBWF), the Federal Ministry for Digital and Economic Affairs (BMDW), and the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK).

A central actor at the regional innovation policy level is the Department for Science and Health within Styria's state administration. It is responsible for the region's public funding programmes and in addition functions as the central office for the "Zukunftsfonds Steiermark" (Future Funds Styria), in order to foster innovative, future-oriented projects in the fields of industry, science, research, education, and also for the Styrian Research Council (Council for Research, Innovation and Future Technologies). Styria's provincial government is also responsible for the coordination of funding activities within the EU ERDF Operational Programme for Styria for 2007-2013 (Programme under Regional competitiveness and employment objective) and 2014-2020.

At the strategic level, the Styrian Research Council acts as a consultant for the state government in the areas of research, innovation and future technologies. Several other agencies offer support and consultancy activities within R&I, such as the Styrian Business Promotion Agency, which promotes and co-finances technology parks, technology clusters and competence centres.

4.2.1 Economic development

For the period to 2025, the government of Styria published their economic strategy (“Growth through Innovation”), highlighting the policies for the future and the leading subjects of the future, namely: technology and creativity, innovation and quality of life, going digital, attractive business location and regions, gapping the bridge between strategic planning and realisation of the future. The Styrian strategy includes also the Smart Specialisation Strategy, which aims at enabling economic growth, expanding employment opportunities and foster competitiveness through innovation, and particularly aims to become a European benchmark in knowledge-based manufacturing.

Mobility, ecological technologies and health technologies remain the main themes of the Styrian economic policy. Creative industries are supported to concentrate more on innovation support and thus play an even greater role in location development. A core target group of the Styrian economic policy are the 2,200 SME´s

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with above-average innovative strength. New funding and financing instruments are being developed so that they can optimally exploit their growth potential[28].

In its economic strategy, Styria aims at a second economic transformation towards high-quality niche products, special solutions, and complex industrial services. Due to this, it acknowledges the crucial importance of "knowledge-based productions", i.e. advanced manufacturing. Further, it considers the IT sector as an enabling technology. Concrete promotion tools are information platforms, such as "AC Styria Business Lounge Industrie 4.0" or "Industrie 4.0 Vorsprung durch Vernetzung" conducted by the Ministry for Economy and Innovation or The Federation of Austrian Industries in Styria[29].

4.2.2 Training and education

Schools and vocational training

Vocational education and training is institutionalized in Austria as the apprenticeship system, and is highly relevant for Styria. It is either as part of a (full-time) school or in the dual system (ISCED 354, EQF 4). At the end of 2018, almost 108000 apprentices were trained in 28.970 companies in Austria. The dual vocational education and training with currently around 220 different apprenticeship occupations takes place at two learning venues – in the training company and in the Part-time Vocational School (Berufsschule) – and offers vocational training that is close to the economy and the labour market. The practical training takes place predominantly in the training company (around 4/5 of the training period). In the Part-time Vocational School (around 1/5 of the apprenticeship period) the focus is on general education, job-specific theory and on deepening the in-company training. Depending on the apprenticeship occupation, training lasts between two and four years and ends with the final apprenticeship examination. Furthermore, the dual training can be combined with a Matura qualification (= general qualification for university entrance); in this case, three additional modules in the subjects German, mathematics and one foreign language as well as an in-depth specialist module must be completed[30].

[28] Source: Die Wirtschaftsstrategie Steiermark 2025, https://www.wirtschaft.steiermark.at/cms/beitrag/10430090/12858597
[29] Source: Regional Innovation Monitor Styria
[30] Source: Federal Ministry for Digital and Economic Affairs

Higher education sector

The university sector in Styria is strong by national standards and features five universities (four thereof located in Graz), two universities of applied sciences and two pedagogic higher education institutions with 63,488 students in 2017/2018. In Upper Styria only two such institutions are located – the Montanuniversität Leoben, a technological university and FH Joanneum a University of Applied Science in Kapfenberg. A strength of Upper Styria is the dense collaboration network with research, public and industrial organisations. Furthermore, HTL (Schools for Higher Technical Education) provide the industry with well-trained young employees[31].

The **Karl-Franzens-Universität Graz,** founded in 1585, is Austria's second oldest university and with approximately 31,000 students one of the largest in Austria. It bundles cutting-edge research in five focus areas, namely Climate Change, BioHealth, Complexity of Life in Basic Research and Innovation, Smart Regulation and Dimensions of Europeanization. The strategic focus "Southeastern Europe" was defined as the core of the university development concept, and university collaborations like “NAWI Graz” (with TU Graz) are especially successful.

The **TU Graz - Graz University of Technology** focuses on five fields of expertise, Advanced Materials Science, Human & Biotechnology, Information, Communication & Computing, Mobility & Production and Sustainable Systems. With 13,500 students it provides high-level expertise for industry and develops key technologies for industry and performs research in the framework of company shareholdings and partnerships.

The **Medical University of Graz** was separated from the faculty structure of the Karl-Franzens-University and transformed into an autonomous university, hosting approximately 4350 students. It has built up a broad spectrum of competencies ranging from basic to applied to clinical-patient-oriented research. The main research areas are Cardiovascular Research, Cancer research, Molecular basis of lipid-associated diseases and Neuroscience.

The **Montanuniversität Leoben (MUL)** with approximately 4000 students takes a unique position with its teaching and research extending from raw material extraction and processing through metallurgy, high-performance materials, process and product engineering to environmental technology and recycling, the focus

[31] Statistik Steiermark, 2018.

on energy technology. Modern manufacturing and manufacturing processes are developed and exported worldwide.

The **University of Music and Performing Arts Graz** hosts 2200 students and combines the Austrian tradition in music and performing arts with the creative potential of European and non-European cultures. It pursues highly qualified teaching with the development and opening up of the arts and with scientific research, with the musicology research cluster.

FH JOANNEUM is a University of Applied Science with the objective to support Styrian business and industry and to strengthen the competitiveness of the region. It is strongly interlinked with know-how from research covering Applied Computer Sciences; Building, Energy & Society; Engineering; Health Studies, Management and Media & Design.

FH Campus 02 Fachhochschule der Wirtschaft offers five fields of study for working professionals, namely Automation Technology, Innovation Management, Information Technologies & Business Informatics, Financial Accounting & Management Accounting, and Marketing & Sales. In 2019, a total of over 5000 students were signed into the business and technical degree programs.

4.2.3 Research and Innovation

The **Austrian Research Promotion Agency (FFG)** offers a comprehensive range of services for Austrian enterprises, research institutions and researchers in all phases of technology development and innovation – from public funding programmes to consulting services, from support for integration into European research programmes and networks to the promotion of Austria's interests at the European and the International level. FFG offers a number of thematic funding programmes for important economic or social topics including energy, cities and the environment, mobility, materials and production, information and communication technologies, safety and security, and space. Many of these projects are undertaken by companies working together with research institutes or universities. FFG increasingly focuses on information and communication technologies, not only in terms of research funding, where already every second euro goes to digitalisation-related topics, but also in building up infrastructure and addressing social and economic structural changes. For example, the FFG is currently implementing the Broadband Austria 2020 programme, and hosts the **Federal Government's Digitalisation Agency**, the central platform for networking, advice and support.

Several federal agencies and institutions are also actively promoting RTDI in the different Austrian states, for example: the **Austrian Federal Economic Chamber (WKO)**, and the **Christian Doppler Association (CDG)** which promotes applied basic research and operates at the interface between science and business. Therefore,

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the CDG provides CD laboratories in which enterprises can gain from the latest findings. Other business-promoting and enterprise-supporting federal agencies are the **Austrian Business Agency (ABA),** which conducts settlement policies for industries, and the **Austria Wirtschaftsservice (AWS),** which among other things provides enterprises with loans and other financial support.

Public sector R&I

A prominent actor in this regard is **JOANNEUM RESEARCH** Forschungsgesellschaft mbH is a professional public research institute, which focuses on applied research and technology development in the areas of materials, health, information and communication technology, water, energy and sustainability, as well as economic and innovation research[32].

Competence Centres. The region is also home to five K1- as well as three K2-competence centres, all of which are run under the national Austrian COMET programme. There are several relevant non-university research institutes in Styria (e.g., a variety of **Christian Doppler Research Association laboratories** in various fields) and the corporate sector finances 75% of research in Styria[33].

Industrial R&I

Industrial research in Styria is supported and coordinated by a number of **industrial clusters**. Among the most important are the

- Mobility Cluster ACStyria, a network of 300 companies from automotive, aerospace and rail systems
- AT Styria – Platform Automation (SMEs in the area of automation),
- Silicon Alps Electronic Cluster, a strategic alliance of Austrian players from industry, science and public authorities to develop and position the electronics and microelectronics sector with a regional focus on the locations Carinthia and Styria
- IT Community Styria, a community to strengthen the software industry in Styria

[32] Source: Regional Innovation Monitor Styria.
[33] Statistik Steiermark, 2018.

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- Several other clusters, e.g., Creative Industries Styria, Green Tech Cluster, Holzcluster Steiermark, Human.technology Styria, the Styrian Service Cluster, and others

Source: Steirische Wirtschaftsförderungs-gesellschaft m.b.H. SFG

4.2.4 Digitalisation strategies and status

National digitalisation strategy

The Federal Ministry for Digital and Economic Affairs claims as its core task to further advance digitalisation and digital transformation in Austria. Priority objectives include the improvement of existing framework conditions to enable digital innovation and technology transfer in the business sector as well as the coordination and implementation of e-government solutions for citizens, business and industry throughout Austria. This includes the electronic signature services, e-government, ICT accessibility and ICT security. The Ministry´s Digital Strategy for Austria aims to de-bureaucratise life and work in Austria, to modernise and digitise the public administration rapidly. In addition to the expansion of broadband and 5G supply, the focus lies on the user-friendliness of digital applications for citizens and businesses.

With the "**Digital Offensive**", the Austrian Federal Government is pushing ahead with the competitive and technology-neutral expansion of nationwide broadband high-performance infrastructures based on the objectives of the "Broadband Strategy 2020". In 2020, an ultrafast broadband high-performance access is due to be achieved nearly nationwide[34].

The digitization of production ("Industry 4.0") means increased efficiency, conservation of resources, increased quality, new, improved business models, security solutions, new forms of organization, digital assistance systems, and changed skills requirements. The **Austrian Platform "Industrie 4.0 Österreich** – die Plattform für intelligente Produktion" was launched by the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) and several public and private interest groups. It aims at ensuring a dynamic development of the Austrian manufacturing sector, at fostering research, innovation and qualification, and at contributing to a high-quality working environment and a high level of employment.

[34] Source: Federal Ministry for Digital and Economic Affairs

Regional digitalisation strategy

In the provincial government's economic strategy for the current period, leading up to 2025 (dated 2016) 'digitalisation' is one of the five main principles. It also highlights S3 policies that aim to lead the area into the future: technology and creativity, innovation and quality of life, digital transformation, the area as an attractive business location or bridging the gap between strategic planning and making the future a reality. Digitalisation is also one of the seven main topics of the Styrian Green Book 2030+ focussing on smart communication, smart cities and regions, smart mobility, smart health and Industry 4.0 (smart production and services).

In 2017, the council has provided ideas and recommendations to strengthen the region of Styria within the concept "Society 4.0". In 2018, the Styrian government began to promote 8 projects on the subject of digitalisation by funding a total of 1.5m EUR. They add the other 297 projects in various fields already being promoted by the initiative[35].

4.2.5 RRI strategies and measures

Regarding gender equality, one of the six areas of RRI, there are several activities in Styria at different levels in place. For instance, the Provincial Government has developed a **Gender Equality Strategy 2020** (Steirische Frauen- und Gleichstellungsstrategie 2020). Its dimensions are, economic independence and a reduction in income inequalities, compatibility of family and professional life for women and men, participation, codetermination and representation of women, violence prevention and protection against violence, reducing gender stereotypes and expanding courses of action, and access to public services and housing.

Zam Steiermark GmbH operates on behalf of the Styrian Labour Market Board (Arbeitsmarktservice AMS Steiermark) and the Provincial Government of Styria to promote professional opportunities for women in the labour market and thereby to increase the competitiveness of companies in the Styrian regions. With 12 locations, training management for women and companies is available across the whole of Styria. The primary goal of zam Steiermark GmbH is to develop needs-based solutions for women interested in training and companies with personnel requirements while at the same time keeping an eye on equal opportunities for women and men in the labour market.

[35] Source: Regional Innovation Monitor Styria

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FIT Steiermark (FIT stands for "Women in Technology and Natural Sciences") is a joint initiative of TU Graz, University of Graz, Art University Graz, FH Burgenland and Styrian colleges to support to support girls in their interests in technical or scientific studies and on their way into the future of technologies. It is supported by the regional government and the Workers Council in Styria. Implemented measures are the annual FIT Info Day to give girls and young women the best possible insight into technical and scientific studies. FIT also focuses on computer courses in summer for girls and awareness-raising in schools.

A recent study for Austria focused on the **inequalities associated with digitalization** (Reidl et al. 2020). Funded by the Laura Bassi 4.0 program of the Austrian Research Promotion Agency (FFG), the analysis points at how inequalities arise or are intensified in the course of technology development and digitization - mostly unconsciously and without intent, but with consequences. On the other hand, ways and means are presented to counter these inequalities and thus to contribute to more equality of opportunity, in terms of gender, age, education, ethnic background, region, or disabilities. Practical examples from Austria are used to illustrate how more people can benefit from new technologies and digitization.

4.3 R&I performance in digitalisation

The central part of the mapping of the DigiTeRRI R&I ecosystem in Styria is to characterize the region with respect to the involved R&I actors and their role in the digitalisation process. We hereby provide quantitative and qualitative analyses of the R&I activities, taking a comparative perspective on the three involved territories, Grand Est, Styria and Värmland. We point out that, due to substantial differences among the territories, a direct comparison of the results, especially a ranking, is often not useful. Nevertheless, we structured the results sections in the same way, so that parallels can be drawn for trans-territorial learning.

The next three sections cover a spectrum of digitalisation activities in Styria starting from i), scientific research to ii), more application-oriented aspects focusing on knowledge exchange between research and industry, and also take into account, iii), the development of new digital technology.

4.3.1 Creation of scientific knowledge

As described in Section 2.2.3, we used data from the Web of Science database (Clarivate Analytics) to analyse the thematic research activities in the region Styria. The identification and request of a relevant number of scientific articles for each region and their analysis was based on the previous definition of a geographic range corresponding to the regarded region, a certain time period, and a relevant thematic focus. Further on we used the software BibTechMon (Kopcsa and Schiebel 2001) for keyword extraction and for further analysis.

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Disciplines, authors, affiliations, keywords and references were extracted from the relevant fields of the database.

Geographic range: Relevant publications with at least one author's affiliation from the Styria region were downloaded.

Time period: Publications in the time range 1998-2020 were taken into account with a result of 6357 publications on the retrieval day July 24th, 2020.

Thematic focus: For further analysis a thematic limitation was made on the basis of Web of Science disciplines. We listed the science disciplines and their numbers of publications and selected core digitalisation relevant disciplines to define the thematic focus. For the later analysis of Research Fields, no previous thematic focus was applied.

Core digitalisation relevant disciplines

The thematic delimitation was based on Web of Science (WoS) Categories as relevant scientific disciplines. By expert judgement, a set of WoS Categories was selected for each territory as having a direct relevance for digitalisation. Thus, core digitalisation relevant disciplines in Styria were identified and listed in Table 11 with their numbers of publications. Radiology, Computer Sciences, Telecommunications, Automation and Control Systems, Remote Sensing, Medical Informatics, Neuroimaging, Robotics, and Mathematical & Computational Biology were picked for Styria as digitalisation-related disciplines.

Table 11. Scientific publications in digitalisation-related disciplines from Styria (2018-20)

SCIENTIFIC DISCIPLINE	NUMBER OF PUBLICATIONS
Radiology, Nuclear Medicine & Medical Imaging	69
Computer Science, Theory & Methods	60
Computer Science, Artificial Intelligence	59
Computer Science, Software Engineering	53
Computer Science, Interdisciplinary Applications	50
Computer Science, Information Systems	49
Telecommunications	47
Automation & Control Systems	43
Remote Sensing	39
Medical Informatics	28

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SCIENTIFIC DISCIPLINE	NUMBER OF PUBLICATIONS
Neuroimaging	19
Robotics	15
Mathematical & Computational Biology	12
Computer Science, Cybernetics	6
Computer Science, Hardware & Architecture	6

Source: Web of Science (WoS); data retrieved July 24th, 2020
Notes: Science discipline relates to the WoS Category; publications can be assigned to more than one category, and are therefore counted multiple times

Digitalisation in the science map of Styria

Figure 8 shows the network of all Styria WoS Categories, with embedded digitalisation relevant WoS Categories (blue nodes in Table 11). This network of co-disciplines shows research activities in medicine on the left side, multidisciplinary sciences and environmental sciences in the bottom, biochemistry in the middle, chemistry and physics on the top, and materials science, engineering, and computer sciences on the right side.

The computer sciences and others strictly related to digitalisation research are marked blue and are found in the lower right part of the network reaching into the left half of the network where medicine is located through neuroimaging and radiology. Interestingly, medical informatics is more linked to the computer sciences and located beneath mathematical and computational biology and computer science, information systems.

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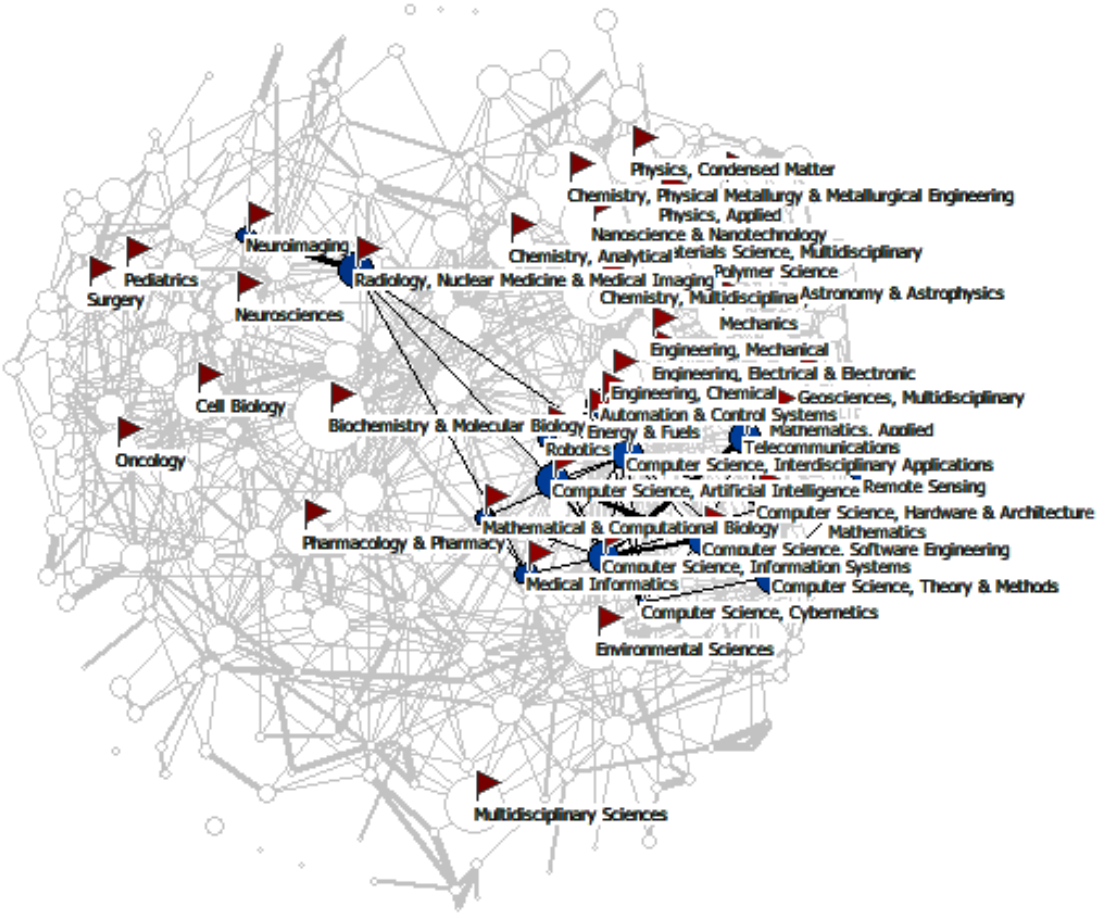

Figure 8. Co-occurrence network of scientific disciplines in publications from Styria (2018-20)

Source: Web of Science (WoS); publications with at least one author from Styria; data retrieved July 24th, 2020.
Notes: Scientific discipline relates to WoS Category; node size refers to the number of publications; length of edges relates to the Jaccard-index of co-occurrence. WoS Categories with less than 25 publications are not displayed. WoS Categories directly relevant for digitalisation are marked blue, with red flags and labels. White nodes with red flags mark disciplines with a number of publications 100 or higher, labels are shown for orientation reasons.

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Publication landscape of Styria

As we intended to find clusters of publications that are related to digitalisation, clusters of similar publications were calculated which can be interpreted as research activities with a critical mass. The map of bunches of similar publications (defined as "*Research Fields*") was drawn as a 3D surface map of the weighted local density of the number of publications (by the Jaccard-Index of links). Hot zones around the peaks were made up of so-called core documents that are highly similar due to a relative high number of common references. In this way Research Fields (RF) created by co-citation analysis (bibliographic coupling) are defined through a similarity-based measure of proximity.

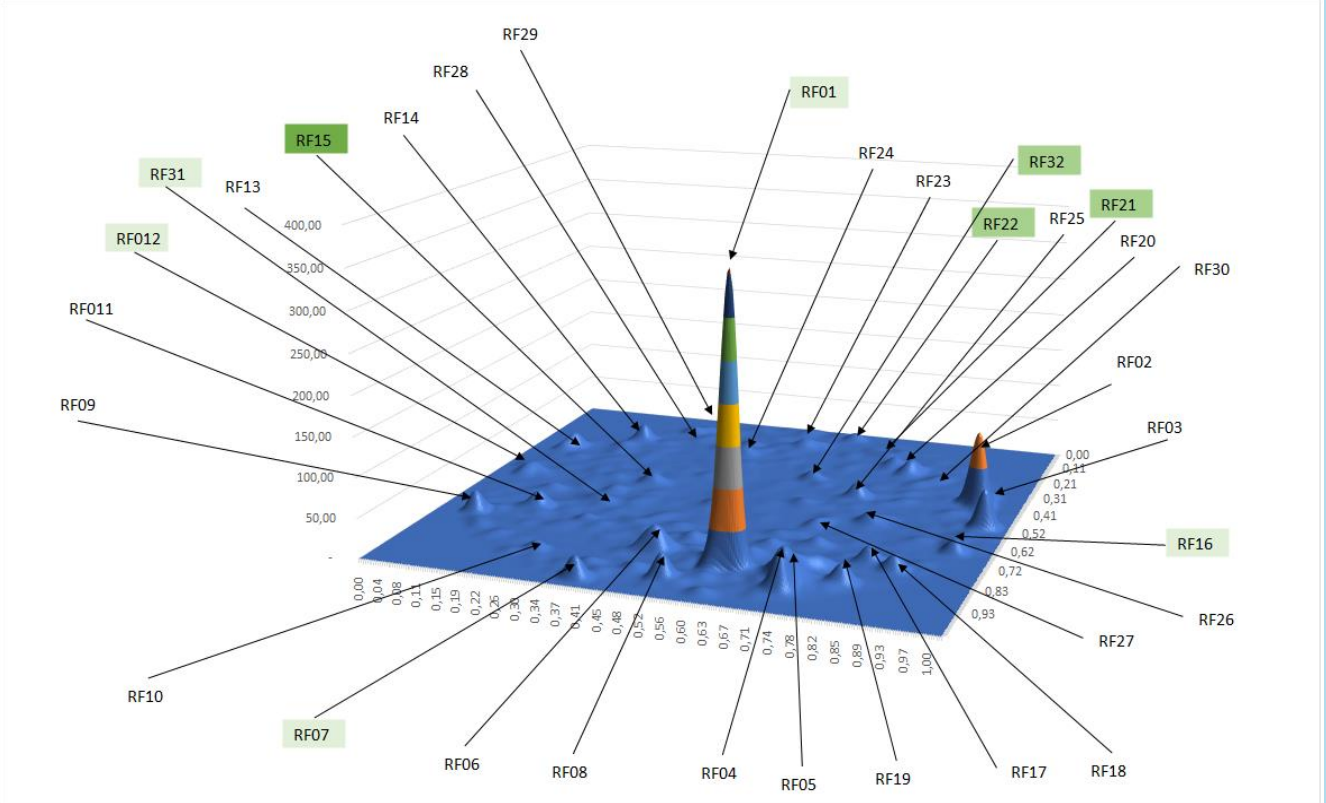

Figure 9. Landscape of publications from Styria (2018-20)

Source: Web of Science (WoS); publications with at least one author from Styria; data retrieved July 24th, 2020.
Note: Map of agglomerations of similar (bibliographically coupled) publications. Proximity is related to the share of joint references, weighted by the number of co-author linkages. Fields with relevance for digitalisation are highlighted: light green: 1 to 5, medium green: 6 to 10 and dark green 10 to 25 publications in digitalisation. Explanation of labels see Table 12 and Table 31 in the Annex.

We mapped the complete research activity in the defined region and time period which is shown in Figure 9. Research activities are indicated with peaks in the landscape of publications. They correspond to the thematic areas of the overall research in the region. In this study we focused on research activities related to digitalisation which are indicated in green colour in the figure. The relevance for digitalisation was calculated by the co-occurrence of Research Fields with disciplines that are highly relevant for digitalisation, see Section 2.2.3 and Table 13.

Figure 9 shows the core Research Fields of the scientific landscape of Styria. The highest peak comprises scientific publications on “Materials Science- ab initio calculations, DFT, visualizations”. The second and third highest peaks refer to Astronomy and Astrophysics. Other significant peaks refer to: Materials Sciences, Chemistry, Physics, and Mathematics.

Thematic focus Styria

Table 12 lists all Research Fields (detected peaks in Figure 9) which were found in direct relevance for digitalisation and their number of publication in Web of Science Categories (WC) which were previously defined as highly relevant for digitalisation. Main focus of the digitalisation literature of Styria was detected in the field of Mathematics, applied - Image reconstruction with 25 relevant digitalisation publications. Also, Neuroscience, Physics, Materials Science, Chemistry, and Environmental Sciences were found as digitalisation Research Fields of Styria.

Table 12. Digitalisation publications in Styria by Research Field (WoS 2018-20)

RESEARCH FIELD		NUMBER OF PUBLICATIONS
RF15	Mathematics, applied - Image reconstruction	25
RF32	Neurosciences - creative cognition	8
RF21	Neurosciences - disgust - skin picking disorder	6
RF22	Mathematics - Giant Component of Random Hypergraphs	6
RF16	Astronomy and Astrophysics - structure constants - laser-generated spectra	2
RF01	Materials Science- ab initio calculations, DFT, visualizations	1
RF07	Physics, Particles and Fields - Gauge theories	1

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RESEARCH FIELD		NUMBER OF PUBLICATIONS
RF08	Chemistry, physical and Material Science: Batteries - Ionic conductivity	1
RF14	Environmental Sciences & Ecology - Arsenic species	1
RF31	Chemistry, physical - Biocatalysis	1

Source: Web of Science (WoS); publications with at least one author from Styria; data retrieved July 24th, 2020.

Key actors in scientific publication

Key actors in scientific publications were identified by repeating the web of science searches for each territory based on postal codes and by combining them with the web of science categories (WC fields) which were previously selected as directly relevant for digitalisation as described above. The list of organizations of publication authors was retrieved from the WoS database by downloading the field "Organizations enhanced" together with the corresponding number of publications per organization. Starting from the organizations with the highest number of publications, it was then checked by desk research, whether the organization belongs to the desired region. A list of the Top 10 organizations was established for each territory (Table 13). Joanneum Research GmbH is found in two different notations in the WoS database of Enhanced Organization names and is therefore listed two times here.

Table 13. Key organizations from Styria in digitalisation-related scientific publication (2018-20)

ORGANIZATION NAME	NUMBER of PUBLICATIONS
GRAZ UNIVERSITY OF TECHNOLOGY	212
UNIVERSITY OF GRAZ	73
MEDICAL UNIVERSITY OF GRAZ	71
BIOTECHMED GRAZ	13
AVL LIST GMBH	11
VIRTUAL VEHICLE RES CTR	9
SIEMENS AG	8
AMS AG	7
JOANNEUM RES	7
JOANNEUM RES FORSCH GESELL MBH	7
KNOW CTR GMBH	7
UNIVERSITY OF LEOBEN	7

Source: Web of Science (WoS), data retrieved September 9th, 2020.
Note: The number of publications cannot be summed up.

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Table 13 gives the list of key actors in scientific publications. In Styria the universities dominate the scientific landscape, followed by research centres such as the collaborative BioTechMed-Graz, the COMET Competence Center VIRTUAL VEHICLE Research GmbH, Joanneum Research GmbH, and Know Centre GmbH. Also among the keyplayers are large companies such as AVL List GmbH, Siemens AG, and AMS AG.

4.3.2 Collaborative research and knowledge exchange networks

EU-funded projects in a region are known to reflect the overall R&I activities quite well, especially in larger and more advanced regions. Thus, the analysis of recent and currently running EU-H2020 projects (derived from EUPRO data base; see Chapter 3 for details) allows to characterize the institutional composition of R&I ecosystems and the infrastructure for knowledge exchange therein. Moreover, the EU Framework Programme fosters international knowledge flows through the requirement to collaborate at a European level, while at the same time has the aspiration to links up with regional R&I.

In Styria, 132 organisations were and are active in a total of 342 H2020 projects (2014 - March 2020). Industry firms (70% of the participants) account for 39% of the project participations and research organizations (14% of the participants) represent 35% of the participations. With regard to universities and higher education organisations (only 5% of the participants) account for 21% of all participations. Note, that since two or more organisations from Styria may be involved in the same project – which are counted as separate participations – the number of participations is higher than the number of projects.

Table 14. Institutional composition of Styria in H2020 digitalisation projects

ORGANIZATION TYPE	ACTORS		PARTICIPATIONS	
	NUMBER	SHARE	NUMBER	SHARE
Education (EDU)	6	5%	102	21%
Research organization (ROR)	19	14%	169	35%
Industry (IND)	92	70%	189	39%
Other (OTH)	12	9%	18	4%
Government (GOV)	3	2%	4	1%
Total	132	100%	482	100%

Source: EUPRO (Status March 2020).

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Thematic profile of Styria´s H2020 digitalisation activities

Digital technologies are seen as an enabler of innovation in virtually all economic and societal activities. To investigate how the digital transformation affects the different sectors of society and industry in Styria, we focus on the thematic profile of Styria´s involvement in H2020. Hereby, we look at the digitalisation project participations and their distribution over the H2020 subprogrammes. The most important subprogramme is "Industrial leadership", combining more than one third of the participations from Styria (see Table 15), which points to a strong aspiration for global competitiveness of the local industry. The relevance for industry is also reflected in the exceptionally high share of innovation in SMEs (8%). The other Thematic Programmes of H2020 of high relevance in Styria are transport and health, represented with 17% and 10% of the participations, respectively. The Thematic Programmes on climate, food security and energy follow with 6%, 5% and 4% of the participations. In comparison, social and societal aspects, e.g., as covered by the programme "Science with and for society" with 3%, are less represented in Styria´s H2020 digitalisation participations.

Table 15. Styria´s digitalisation project participations in H2020 sub-programmes

SUBPROGRAMME	PARTICIPATIONS	
	NUMBER	SHARE
Industrial leadership	156	35%
Smart, green and integrated transport	75	17%
Health, demographic change and well-being	46	10%
Innovation in SMEs	35	8%
Climate action, environment, resource efficiency and raw materials	29	6%
Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy	23	5%
Secure, clean and efficient energy	20	4%
FET Future emerging technologies	14	3%
Developing new world-class research infrastructures	14	3%
Science with and for society	14	3%
Secure societies - Protecting freedom and security of Europe and its citizens	9	2%
Europe in a changing world - inclusive, innovative and reflective societies	8	2%
Spreading excellence and widening participation	5	1%
H2020 Total	448	100%

Source: EUPRO (Status March 2020).
Note: participations are subject to multiple counting due to joint calls of the H2020 subprogrammes.

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Key players from Styria in H2020 digitalisation projects

To round up the sectoral analysis of Styrian participation in H2020 digitalisation activities (given in Table 14), we now shed light on the most frequent H2020 participants from the region (see Table 16). Participation is strongly concentrated in a relatively small number of organizations, given that the Top 10 participants account for no less than 59% of all participations, and comprise 4 research organizations, 4 universities and 2 industry firms. Above all, the digitalisation activities from the automotive sector have to be mentioned, with the Virtual Vehicle Research GmbH, AVL List GmbH and Technische Universität Graz. The other top participants are Joanneum Research, University of Graz and organizations from the Health and Biomed sectors, as well as from materials science, to name Montanuniversiät Leoben and MCL. At rank 10 on the list of the top organizations is the first digital technology provider, AMS, a global player in semiconductor production.

Table 16. Top 10 organizations from Styria in H2020 digitalisation projects

ORGANIZATION NAME	TYPE	NUMBER OF PARTICIPATIONS
VIRTUAL VEHICLE RESEARCH GMBH	ROR	60
AVL LIST GMBH	IND	57
TECHNISCHE UNIVERSITAET GRAZ	EDU	51
JOANNEUM RESEARCH FORSCHUNGSGESELLSCHAFT MBH	ROR	34
UNIVERSITAET GRAZ	EDU	18
BIOBANKS AND BIOMOLECULAR RESOURCES RESEARCH INFRASTRUCTURE CONSORTIUM (BBMRI-ERIC)	ROR	15
MEDIZINISCHE UNIVERSITAT GRAZ	EDU	15
MONTANUNIVERSITAET LEOBEN	EDU	13
MATERIALS CENTER LEOBEN FORSCHUNG GMBH	ROR	10
AMS AG	IND	9

Source: EUPRO

Although the industry sector in Styria is very strongly represented in H2020 digitalisation projects, the top players are mainly non-firms (with the exception of AVL, a leading automotive system developer). But the main H2020 activities in the field are carried out by industry-oriented research organizations and universities in Styria. This reflects the finding that smaller companies contribute the lion´s share to the comparatively large number of industry firms among the participants in H2020 digitalisation projects.

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Styria´s digitalisation networks of in EU-H2020

Due to the enabling character of digital technologies throughout the economy, related activities are both ubiquitous and application-specific, especially in R&I, which makes the identification of concrete activities difficult. Therefore, we distinguish between two groups of R&I projects and use this distinction as an analytic device for investigating knowledge flows in the R&I ecosystem. First, we define “development-oriented” projects as projects focused at the development of new digital technologies, methods or basic concepts (like, for instance, projects dealing with data stream analysis), and second, “application-oriented” projects, which are such projects that are deeply rooted in application fields (like projects on digital factories or rail operations). For this purpose we use specific thematic keywords that are available for each H2020 project, and group them into two disjoint sets of keywords, namely development-oriented and application-oriented keywords (for the lists of keywords, see Table 36 and Table 37 in the Annex).

Filtering the Styrian projects for these two sets of keywords, we obtain two (partly overlapping) sets of projects with development aspects on the one hand, and application aspects on the other. The share of development-only digitalisation projects is 6%, while 60% are application-only projects. The large overlap of these two sets of projects (34% of the projects) highlights the fact that there is a wide range of project types from pure development to strong application embeddedness, and that a clear distinction is virtually impossible, again underlining the pivotal role of digitalisation in the broader R&I field.

Development project network of Styria

In Styria, we identify a total of 136 development-oriented digitalisation projects in H2020 (40% of all digitalisation projects with Styrian participation, which is a low share as compared with application-oriented projects). Since we are interested in the knowledge exchange within the R&I ecosystem of Styria, we look at how participations from Styria are linked with other Austrian and international partners (from 48 countries) in these projects, applying network visualization techniques. In the network diagram (Figure 10), the nodes represent the participations by organization type and affiliation country, whereby participations from Styria are separated from other Austrian participations. Thus, for instance, a French industry firm from Grand Est contributes to FR-IND, a University from Värmland comes in as SE-EDU, while a research organization from Vienna counts for the group AT-ROR. For greater clarity, the network diagram shows only nodes with participation numbers equal to 5 or higher, leading to a network with 82 nodes.

What we find in development-oriented digitalisation projects with partners from Styria is a strongly industry-led and centralized network, with German industry as the by far most important hub at its very centre (DE-IND, with 297 participations), but also with Italian, Spanish, French, Dutch and other industry firms accompanying the

wider core of the network. This wider core is complemented by universities and research organizations from Germany and other countries, mainly from the former EU-15. The periphery of the development network is formed by the sectors mainly from new member states and associated countries of the EU. All partners of Styrian development-oriented digitalisation projects are from the EU- or associated countries.

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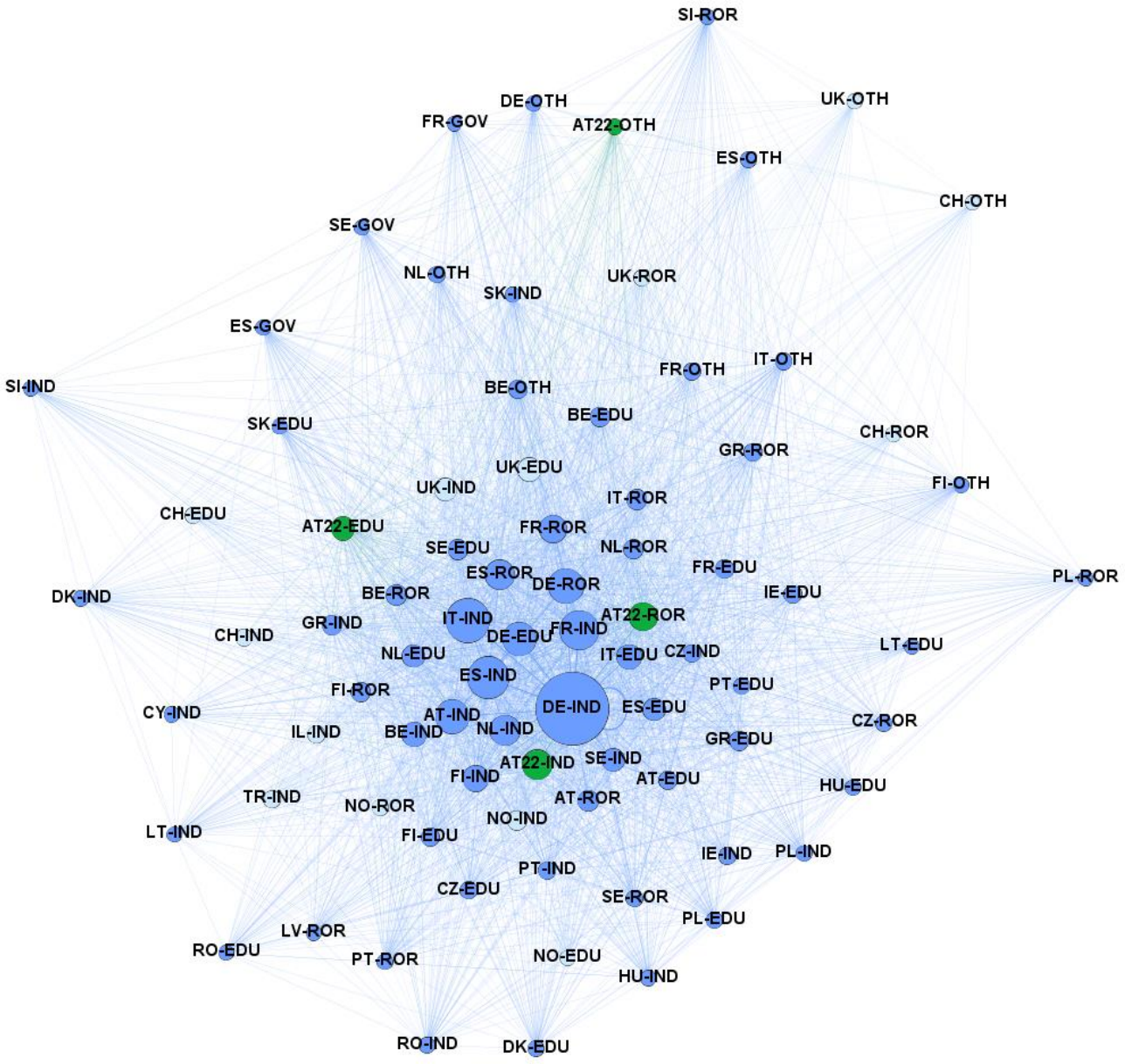

Figure 10. H2020 collaboration network of Styria in development-oriented digitalisation projects

Source: EUPRO (Status March 2020).

Note: Nodes refer to partner country and type of organizations, node size corresponds to the number of participations from this group ($5 \leq n \leq n_{max} = 297$). Links refer to joint project participations, node distance corresponds to the relative frequency of joint project participations. Styria is distinguished (nodes in green and labels AT22-x) from the rest of Austria (labels AT-x). Node colours indicate country groups. For organization type codes, country groups (colour of nodes) and country codes, see Table 34 and Table 35 in the Annex.

The position of Styria in the development network is quite central, being embedded in the wider core of the network. Especially industry participations from Styria (AT22-IND) are closely connected to the hub, i.e. German industry, but also to industry partners from the Netherlands, Sweden and Finland. The research organizations sector (AT22-ROR) is strong in terms of participation numbers and situated in the wider core of the network as well. However, is more strongly connected with French industry and universities and research partners from Italy, Germany, Spain and other West-European countries. The university sector in Styria (AT22-EDU), despite high participation numbers in development-oriented digitalisation projects, is more weakly connected to the industrial network core, but shows a high variety of partner countries and organization types.

Application project network of Styria

In Styria, we identify 323 application-oriented digitalisation projects in H2020, representing 94% of all digitalisation projects with participations from the region. Compared with the 40% share of the projects with development-oriented aspects, this underlines the high penetration rate of digitalisation technologies and at the same time the strong mutual dependency of both aspects in Styria. Looking at the collaboration network of Styria, we can draw conclusions for corresponding knowledge flows among the involved organizations, both within the region and beyond. International partners are from 71 countries worldwide.

Applying network visualization techniques, we obtain the network diagram presented in Figure 11. Nodes stand for project participations from a certain organization type and country, whereby Styria (labelled AT22_x and coloured green) is separated from the rest of Austria. Nodes with less than 5 participations are cut off in order to carve out network structures in a clearer way. With 118 nodes, the application-oriented network is significantly larger than in the development-oriented case, and more densely connected, so that the core of the network is larger and less easy to separate from the peripheral areas.

What we thus see here is a much more heterogeneous network with respect to country involvement as with the development-oriented projects. Virtually all EU-27 and associated countries are involved in the Styrian application-oriented projects, and even overseas High-income Countries and International Cooperation Partner Countries like China, Kenya and South Africa are present with their research sectors. Remembering the cut-off below 5 participations, makes this observation especially remarkable. Again, led by German industry (DE-IND) in terms of participations (446), the core of the network is densely connected, but much more heterogeneous in terms of organization types: Both universities and research organizations from the central European countries join the usual industry club of the core actor groups.

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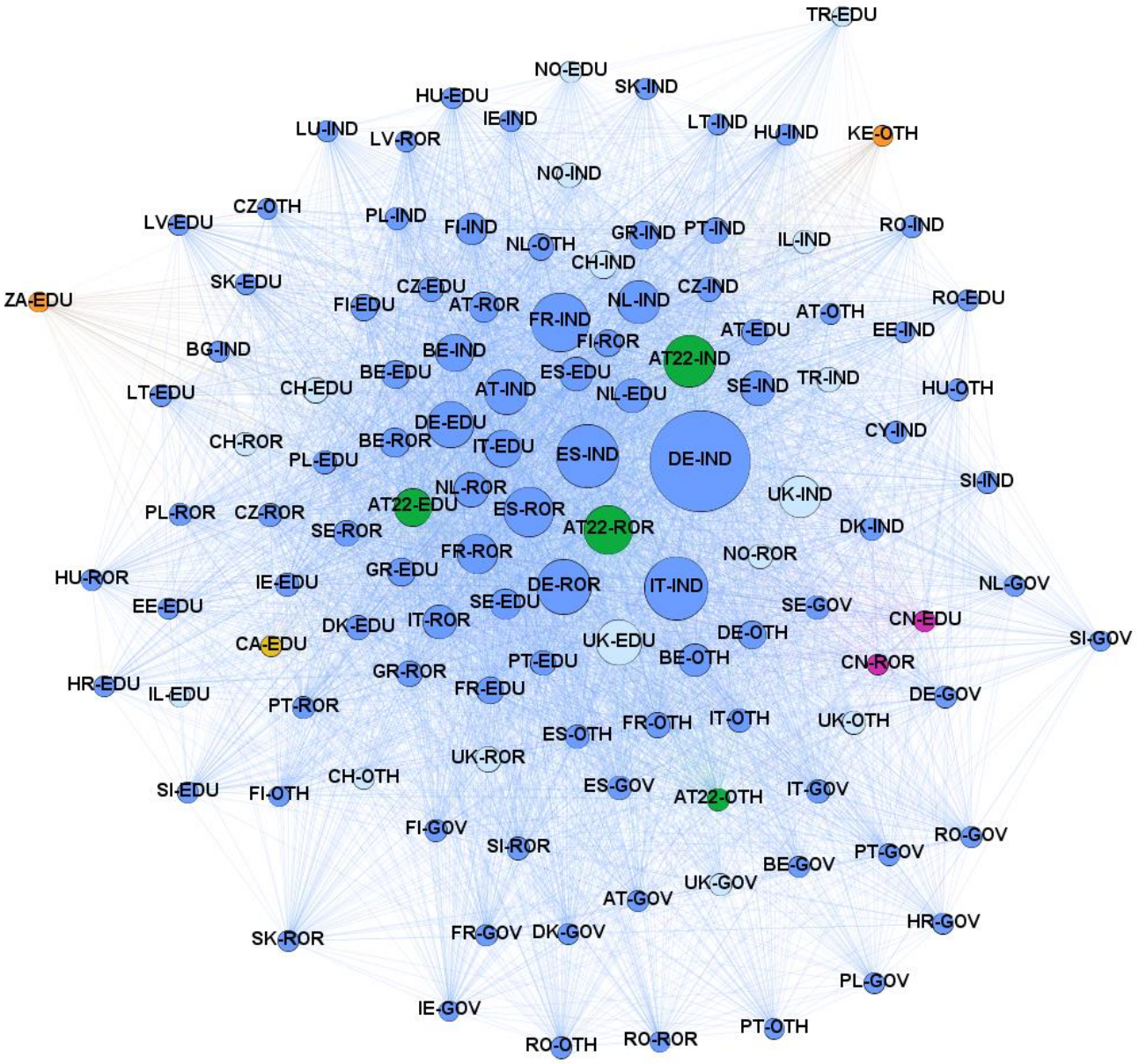

Figure 11. H2020 collaboration network of Styria in development-oriented digitalisation projects

Source: EUPRO (Status March 2020).

Note: Nodes refer to partner country and type of organizations, node size corresponds to the number of participations from this group ($5 \leq n \leq n_{max} = 446$). Links refer to joint project participations, node distance corresponds to the relative frequency of joint project participations. Styria is distinguished (nodes in green and labels AT22-x) from the rest of Austria (labels AT-x). For organization type codes, country groups (colour of nodes) and country codes, see Table 34 and Table 35 in the Annex.

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Organizations from Styria are very deeply embedded in the core of the application-oriented network, whereby Styrian industry (AT22-IND) is close to the German, but also other large European industry sectors. Research organizations from Styria (AT22-ROR) are located very centrally in the mixed-organization-type core of the collaboration network, and also universities from Styria (AT22-EDU), though slightly lower in participation numbers, remain quite well connected to the dominant group of core university sectors. Summing up, Styria´s organizations in H2020 digitalisation projects play a very central role in their application-oriented networks, underlining the strength of the region in fostering the enabling role of digital technologies in a wider technological and societal context.

Styria in the national digitalisation project network

Knowledge exchange is not only important at the international level, but also more locally, at the regional and – for a small country like Austria – at the national level. We are interested in digitalisation-oriented collaborative R&I activities funded at the national level in Austria with involvement of Styrian organizations, and analyse the corresponding collaboration network, in order to cover knowledge exchange structures with a stronger focus on organizations from the regional R&I ecosystem in Styria. Hereby, we use collaboration data derived from national research funding programs issued by the Austrian Research Promotion Agency (FFG). FFG is the national funding agency for industrial R&D in Austria and – alongside with other roles – finances R&D in the business and science sectors, impulse programmes, research facilities and networks fostering cooperation between science and industry.

We select for projects funded by FFG in the period 2015-2020, assigned to the theme “IKT” (information and communication technologies), among all available programmes, e.g. “ICT of the Future”, “ECSEL” or “Production of the Future”, to name but a few. This basic selection results in 469 digitalisation projects with 221 partner organizations from Styria[36], comprising 190 companies (86%), 5 universities, 13 research organizations and 13 intermediary or other organizations.

Applying network visualization techniques, we obtain the network diagram presented in Figure 12. Nodes stand for project participations coming from a certain organization type and country, whereby Styria (labelled AT22_x and coloured in green) is distinguished from the rest of Austria. The resulting network consists of 86 nodes

[36] The used database is continuously updated backwards in time. At the time of retrieval, it included mostly projects from 2015 onwards. Project data are only published with the consent of the beneficiaries.

(organization types from countries, e.g. US-IND), whereby node size corresponds to the number of project participations from this sector/country. Links represent joint project participations whereby proximity refers to the number of joint participations. Therefore, higher numbers of joint project participations lead to closer co-location of nodes in the network.

What we find is a strong network core of Austrian organizations with all organizations from Styria closely attached due to frequent joint project participations, and a vast area of peripheral nodes coming from international participations. This is no surprise, for two reasons: First, the funding programs behind the data are directed primarily towards Austrian beneficiaries, and second – by our method – we use an ego-network approach for Styrian participants. What is more interesting, however, are the relative positions of the individual sectors and the immense breadth of international involvement, with no less than 42 countries worldwide involved.

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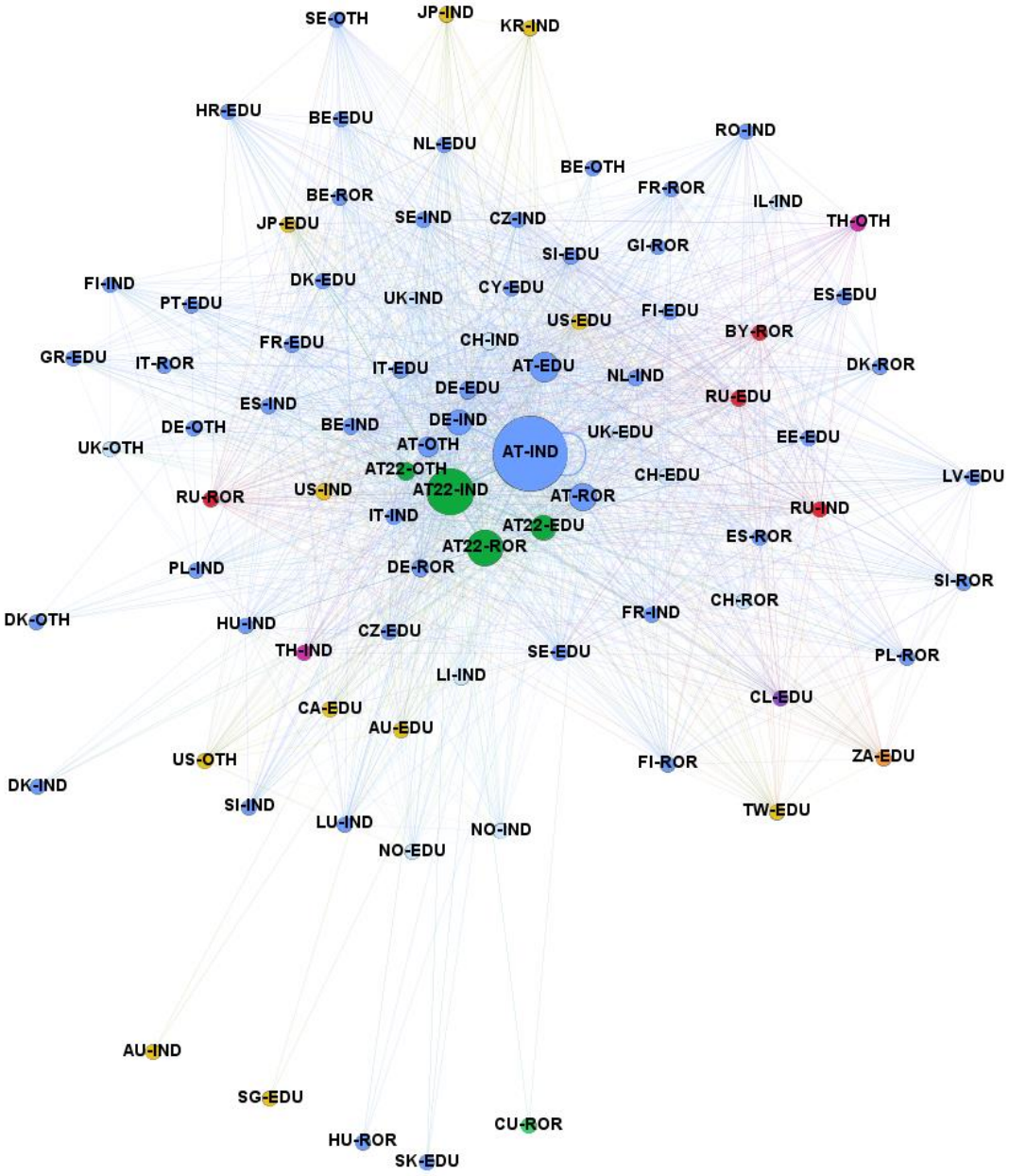

Figure 12. Regional-level collaboration networks in Styria

Source: EUPRO/FFG (Status: 26 May 2020)

Note: Nodes refer to partner country and type of organizations, node size corresponds to the number of participations from this group ($2 \leq n \leq n_{max} = 924$). Links refer to joint project participations, node distance corresponds to the relative frequency of joint project participations. Styria is distinguished (nodes in green and labels AT22-x) from the rest of Austria (labels AT-x). Intermediary organizations and other organizations are coded as OTH and may also include governmental organisations (municipal authorities etc.). Node colours indicate country groups. For country and organization type codes see Appendix (Table 38 and Table 39).

Styrian industry firms (AT22-IND) are most closely linked with industry firms from elsewhere in Austria (AT-IND) and Other Organizations from Styria (AT22-OTH); also Styrian research organizations (AT22-ROR) are frequent collaborators, while universities (AT22-EDU, but especially AT-EDU) are less closely linked to Styrian industry. Also associated countries are relatively close to but not within the Austrian core network; we find also sectors from overseas High-income countries, like US-IND, US-EDU at this medium distance. A final observation that is worthwhile highlighting is the extensive outreach of digitalisation-related projects emerging from the national funding activities. Hereby, we find industry, research and university sectors from all European, and High-income countries like Australia, Canada and Japan, at the periphery of the network, but nevertheless connected. Moreover, participants from International Cooperation Partner Countries (ICPCs) from all continents are involved in Styrian digitalisation projects, highlighting the efforts towards global collaboration.

4.3.3 Development and application of digital technologies

The analysis of the patenting activities allows the characterization of the territorial R&I ecosystem from the perspective of the development of technology and innovation. Based on the International Patent Classification (IPC), we focus on technology classes which are especially relevant for digitalisation – information and communication technologies (ICT) – using the standard OECD assignment of patent subclasses to ICT fields (see Table 33). Since each patent is assigned to one or multiple patent classes, this kind of data is very well-suited to gain insights into the ICT-internal distribution of technologies, and their influence on other technologies, and thus the whole technological spectrum of the territorial R&I ecosystem.

Patents in Information and Communication Technologies (ICT)

Retrieving PCT patents from the PATSTAT database with applicants from Styria (NUTS code: AT22) in the period 2014-2018, we identify a total of 1,810 patents of which 35% are assigned to at least one ICT field. This set of 625 ICT patents was selected for further analysis, whereby 152 organizations from Styria involved as applicants. The subsequent analysis is based on fractional counting, i.e., in case a patent is assigned to more than one patent class, these patent classes receive respective shares of the patent count. Mutatis mutandis is applied to multiple applicants. In this way, we obtain weighted numbers for the comparison of subsectors.

In total, Styria accounts for 374.8 ICT patents (fractional counting) in the period 2014-18, representing 27.1% of the total patenting activity (1,380.7 patents) in Styria (Table 17). This is a much higher share than both in Grand Est and in Värmland, indicating a relative technological strength of Styria in this sector. Contrasting the total number of 625 ICT patents (full count) with 374.8 by fractional counting also reveals a high importance of ICT for other technologies: 40% of the patent class assignments of ICT patents is with non-ICT classes in Styria. Within

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ICT fields, with almost two thirds of the patents (242.1), “Other ICT” is the most outstanding, subsuming subclasses on measurements and semiconductor technologies. “Computers, office machinery” accounts for 63.5 patents and 44.4 patents go on “Telecommunications”. Less important for Styria is the field “Consumer electronics”, comprising 24.8 patents during the covered application period (1.8% of all patents).

Table 17. ICT patents from Styria by subclasses (2014-18)

ICT SUBCLASS	PATENTS		
	NUMBER	SHARE	RTA
Computers, office machinery	63.5	4.6%	0.71
Consumer electronics	24.8	1.8%	1.15
Other ICT	242.1	17.5%	1.89
Telecommunications	44.4	3.2%	0.42
Total ICT patents	374.8	27.1%	1.09
Total patents	1380.7	100%	1

Source: PATSTAT
Note: Calculations based on fractional counting

The Revealed Technological Advantage (RTA) is a well-established measure of technological specialization of a a regional economy; it can be measured in terms of obtained patents (for details on the methodology see Chapter 2). The figures for the RTA in Table 17 relate ICT patenting in Styria to the European level (EU28 plus Switzerland and Norway). The results show a relative overrepresentation of total ICT patents in Styria as compared with the European average (with an RTA value of 1.09). This relative strength of the overall ICT patenting in Styria is mainly induced by one outstanding subfield of ICT, namely “Other ICT” (with an extremely high RTA value of 1.89, mostly related with semiconductor patents). But also “Consumer electronics” exhibit an RTA value well above 1, namely 1.15. In contrast, “Computers, office machinery” are underrepresented in Styria, and a relative weakness can be observed in “Telecommunications”, with an RTA value of 0.42.

Key patenting actors in ICT

The Top 10 actors in digitalisation-related patenting in Styria are all companies, which is no surprise, since patents are generally considered as output of industrial innovation efforts, characterized by application oriented and exploitation-driven research, and serve as a main means of protecting a firm´s intellectual property. Hereby, large multinational semiconductor and (micro-)electronics companies (AMS, TDK, AT&S, Siemens) are in the lead, but also Automotive engineering/powertrain (AVL), and Telecommunications (Ericsson) are among the

most important players in Styria. Also, smaller but still globally active companies from the region are ranking top in this list. Compared with this industrial dominance, public research and university actors take a back seat, although there are remarkable patenting activities (Joanneum, MCL, TU Graz, to name the most prominent) in Styria.

Table 18. Top 10 applicants for ICT patents in Styria (2014-18)

ORGANIZATION NAME	NUMBER OF PATENTS
AMS AG	114.0
AVL List GmbH	100.2
TDK Electronics AG	55.5
Telefonaktiebolaget LM Ericsson (publ)	36.0
AT & S Austria Technologie & Systemtechnik Aktiengesellschaft	22.5
Usound GmbH	20.0
Epcos AG	12.5
Tridonic Jennersdorf GmbH	10.5
Siemens Aktiengesellschaft	10.0
Anton Paar GmbH	9.0

Source: PATSTAT
Note: patents in fractional count.

Unlike in Grand Est, ICT patenting strongly concentrated in Styria: The Top 10 applicants account for 62% of the ICT patents, reflecting the presence of large global industrial firms which are world leaders in semiconductors, microelectronics and instruments.

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CHAPTER 5: THE DIGITERRI R&I ECOSYSTEM IN VÄRMLAND

This chapter presents the mapping of the R&I ecosystem in Värmland with a special focus on its digitalisation activities. As a peripheral territory, Värmland is facing typical challenges related to rural-urban migration, ageing population, gender imbalance, and relatively low participation in higher education. Through a clustering approach and smart specialisation, Värmland is effectively moving from traditional pulp and paper operations into adopting a bioeconomy approach. Cluster organizations, like the “Paper Province”, act as key drivers for the regional economy and innovation and strongly support the region to embrace the European regional smart specialisation strategy.

According to the mapping methodology (see Chapter 2 for details), the results for all three territories are structured in the same way ensuring comparability despite large differences in terms of size, concrete industrial and technological structure and governance. First, a brief account of the socio-economic profile of Värmland is given, covering the aspects industry structure, employment, education and figures on R&I activities. Section 5.2 sketches the institutional setup of the R&I activities, the related governance structures and the government strategies. Section 5.3 describes digitalisation relevant R&I activities applying descriptive statistical and network analysis methods. It focuses on the creation of scientific knowledge, on knowledge exchange in collaborative research, and finally on technology development aspects.

5.1 Socio-economic profile

The Värmland region (Värmlands län) is part of the NUTS2 region North Middle Sweden (Norra Mellansverige). Värmland is facing important challenges, such as slow population growth, a low level of education, low wages and a low degree of employment compared to the Swedish average. The population of the region was 281,482 inhabitants in 2019, this being an increase of 2.8% since 2014. Värmland borders Norway and the Oslo region and is thus a border region in the EU. Proximity to Oslo is an important condition for business and employment. Companies in Värmland are dependent on good communications due to the long distances to metropolitan regions. In terms of export and value added in forestry, Värmland is second in Sweden after

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Västernorrland. Thus, forests are an asset for the region and its strategy. The public sector provides most of the jobs in Värmland, followed by the manufacturing and steel industries and retail trade industry[37].

5.1.1 Industrial structure

Värmland's industry is concentrated in a few dominant sectors. The two industries with the highest turnover in Värmland are the basic and manufacturing industries and trade. Together, these two industries account for two thirds of the total turnover in the county. The biggest industries are pulp and paper (approx. 4,000 employees), steel and engineering (10,000 employees), IT (2,000 employees) as well as tourism (3,000 employees), which is the fastest growing. Research and innovation is evolving within these industries, both within the companies and the academic world. A vital part of any business network is a well-developed infrastructure for corporate services including knowledge-intensive business services (KIBS). These companies often provide services to different industries, which makes them important bearers of knowledge in the region. Generally, industry is well-organised in cluster initiatives and networks.

5.1.2 Employment

The largest sectors in Värmland according to employment are Health and social care; social services with 22,595 employees in 2018 (Statistics Sweden's SNI division: Q), Manufacturing and extraction; energy supply and environmental activities with 18,606 persons (SNI-codes B, C, D, E), Corporate and organizational services with 16,796 people (SNI-codes J, K, L, M, N), Trade with a total of 13,766 people (SNI-code G), and Education comprising 13,608 employees (SNI-code P).

The labour market in Värmland is strongly gender-segregated: Over half of all women work in welfare, but only 11% of men. Among men, 39% work in industry or construction, while only 7% of women are employed in these industries. Looking at the addressed largest individual sectors, this gender segregation is as follows: in Health and social care, 83.2% between the ages of 20 and 64 were female employees in 2018 in Värmland, while in Sweden as a whole, only 79.9% of employees were women. Similarly, in Education, the female share of employment was higher in Värmland (76.2%) than in Sweden as a whole (74.4%). In Trade, the share of female employees was 44.6% in Värmland, equalling the Swedish national share in 2018. The situation starts getting

[37] Source: Region Värmland (2015). https://www.kau.se/files/2017-12/Strategy%20Smart%20Specialisation%202015-2020.pdf

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different in Corporate and organizational services: Here the share of women is 38.5% in Värmland, and higher in Sweden as a whole (41.0%). Even lower is the share of women in Manufacturing and extraction; energy supply and environmental activities, with 21.2% in Värmland, while in all Sweden this share is 24.1%. Finally, in Construction female employment in Värmland is 6.8% while the Swedish total amounts to 9.6% female employees. Summing up, employment structures in Värmland seem to be significantly more inclined to traditional gender roles regarding employment.[38]

5.1.3 Education

The level of vocational training is decreasing, but still higher in North Middle Sweden (SE31) as compared with all of Sweden. With 30.7% of the population aged 30 to 34 years having achieved upper secondary and post-secondary non-tertiary education (levels 3 or 4) in vocational training, the region is well above the Swedish national level (22.4%) in 2019, which is itself a low value in international comparison. The observed gap has been reduced during the last 5 years due to a decrease of vocational attainments in North Middle Sweden, while the overall Swedish level remained constant. Among women, the share of vocationally trained persons is lower in North Middle Sweden (24.3%) – but still far above the Swedish level (16.7%). Both Sweden and North Middle Sweden witnessed a moderate decrease in female vocational training in the last 5 years.

Educational attainment at university-level is generally very high in Sweden, and North Middle Sweden has achieved a remarkable catch-up in the last 5 years. Among all 30- to 34-year-olds, 46.8% have achieved tertiary education (ISCED11-levels 5-8), which is below the Swedish national level (52.5%) in 2019. North Middle Sweden started from 38% of the population with a university degree in 2014, when the gap to the Swedish level was almost 12 percentage points, the gap was nearly cut in half by 2019. It is important to note that, this is mainly due to female education. Tertiary education among women is even higher than with men in all of Sweden: 59.9% of the 30- to 34-year-old women have achieved tertiary education levels in Sweden in 2019, with a slight increase from 2014. Regarding the region North Middle Sweden, women have tremendously caught up since then, reducing the gap from 10.2 percentage points to 2.3, resulting in a share of 57.6% for women in tertiary education attainments in 2019[39].

[38] Source: Region Värmland
[39] Source: EUROSTAT

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5.1.4 Research and innovation

Research and innovation performance in Värmland is low compared with Sweden. It is being described as a "follower" region in terms of innovation but still ahead of the EU average in some respects. In terms of performance indicators, data from EUROSTAT are available from North Middle Sweden (Norra Mellansverige) rather than from Värmland County. Referring to that observational unit, the total regional expenditures on R&D (GERD) have been decreasing since 2013 and amounted to 0.39bn EUR in 2017 in North Middle Sweden, representing 1.2% of the regional GDP – a share substantially lower as compared with the 3.37% at the national level in Sweden – an international forerunner in R&D expenditure. While the business sector increased its R&D expenditures from 2.26% of the GDP in 2013 to 2.4% in 2017, the R&D expenditures in the business sector of North Middle Sweden decreased from 1.09% to 0.97% in the same period.

Regarding Innovation expenditures, we refer to the Regional Innovation Scoreboard (RIS; based on the Community Innovation Survey), which is a regional extension of the European innovation scoreboard, assessing the innovation performance of European regions on a limited number of indicators. The resolution of the RIS is only available at the level of North Middle Sweden (Norra Mellansverige, SE31), so we rely on those figures to proxy the situation in Värmland (SE311). We therefore have to mind that the presented figures in Table 19 combine the three NUTS3 Counties Värmland, Dalarna and Gävleborg.

Table 19. North Middle Sweden (SE31) in the Regional Innovation Scoreboard 2019

INDICATOR	SCORE RELATIVE TO	
	SWEDEN (=100)	EU (=100)
Regional Innovation Index 2011	*65.8*	*94.4*
Regional Innovation Index 2019	66.8	90.8
Tertiary education	82	118
Lifelong learning	91	264
International scientific co-publications	37	55
Most-cited scientific publications	60	64
R&D expenditures public sector	43	52
R&D expenditures business sector	67	89
Public-private co-publications	47	85

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INDICATOR	SCORE RELATIVE TO	
	SWEDEN (=100)	EU (=100)
PCT patent applications	66	123
Trademark applications	52	78
Design applications	71	71
Employment in medium and high technology manufacturing / Knowledge intensive services	65	86

Source: Regional Innovation Scoreboard 2019. For details of the scoreboard methodology, see https://data.europa.eu/euodp/de/data/dataset/regional-innovation-scoreboard.

Innovation performance in Värmland is low compared with Sweden. It is being described as a follower region in terms of innovation but still ahead of the EU average some respects. According to the Regional Innovation Scoreboard, North Middle Sweden – the region which the County Värmland belongs to – has been catching up slightly with respect to all of Sweden during the period 2011-2019. While it outperforms the EU average level by far in terms of tertiary education and life-long learning, it lags remarkably behind in terms of R&D inputs (R&D expenditures) and scientific output indicators (publications). Technology output, as measured in PCT patents is low as compared with Sweden but still high above the EU level (123). Employment in medium and high technology and knowledge intensive service sectors is still lower than at the national and European level.

5.2 R&I governance, strategies and institutional setup

Public involvement in the R&I system in Sweden can be grouped into four categories: i) Developing policies on national and regional level (parliament, government, ministries, local authorities and county councils), ii) support for implementation of policies and financing of R&I (research funding institutes; VINNOVA – the agency for innovation systems, sectoral agencies), iii) implementation of R&I (universities and research institutes), and iv) support for commercialisation and entrepreneurship (e.g. the agency for economic and regional growth - Tillväxtverket, ALMI, incubators). The level of regional autonomy concerning regional innovation policies in Sweden is rather high. The European Regional Development Fund (ERDF) Programme has considerably contributed to the development of innovation platforms in the region.

The **Region Värmland County Council** represents the region´s principal administrative subdivision of Sweden. It holds responsibility for certain public functions within the county, like regional development, health care, culture, education and public transport, and has the right to levy taxes. The County Council Assembly is the highest decision-making authority in Region Värmland and is comprised of 81 Members which are elected by the county electorate every four years. **Region Värmland** is its operative arm and responsible for development and

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implementation all of the county of Värmland's strategies. Its strategic areas are, quality of life for everyone, more and stronger companies, higher competence and better communications. Region Värmland employs close to 8,000 people[40].

An important resource for regional innovation in North Middle Sweden is **Karlstad University**. In several of its research areas, the university works closely with the regional business community. It is part of a cross-regional innovation office, focusing on commercialisation. In Värmland, the **Academy for Smart Specialisation**, based on funds from academia, Region Värmland and the private sector is an important policy instrument serving as a meeting place for researchers, companies, financiers and entrepreneurs related to, among other, the Forest-based Bioeconomy[41].

5.2.1 Economic development

The industrial development of Värmland has been traditionally dependent on the region's natural resources, particularly its vast forests. The innovation system is formed around cluster initiatives, collaborations with regional higher education institutions and innovation platforms, e.g. the Paper Province (pulp and paper, which merged with Packing Arena), Triple Steelix (steel and engineering) and Compare (ICT).

In North Middle Sweden, much has been done (at NUTS 3 level) to develop the innovation system, sharpen specialisation and enhance overall innovativeness. The regions are required to present a regional development strategy, often developed in partnership with actors of different sectors, e.g. business, public sector, universities and non-profit organisations, have incorporated the European Union´s S3 agenda. In Värmland, with businesses active along the entire value chain, the Paper Province 2.0 provides benefits that boost both development and results: PP member companies have had a three-times-higher growth rate than the county as a whole and a profitability that is 6.8% higher than that of the average Swedish company. In 2015, Värmland developed a research and innovation strategy (Research and Innovation Strategy – Smart Specialization 2015-2020) that functions as both a regional innovation and smart specialisation strategy[42].

[40] Source: Region Värmland https://www.regionvarmland.se/om-regionen/Om-webbplatsen/English-engelska/
[41] Source: Mapping of EU Member States' Research and Innovation plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy. Case Study Report Värmland, Sweden. https://www.sbhss.eu/files/Ovrigt/Case-Study-Report-Vrmland_SE.pdf
[42] Source: Regional Innovation Monitor North Middle Sweden

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5.2.2 Training and education

Schools and vocational training

In the last decade, Sweden has introduced a wide range of reforms in its upper-secondary vocational education and training (VET) system. It has enhanced work-based learning by introducing stricter requirements on the provision of work placements by schools in vocational programmes and the role of the social partners by creating national architecture in which social partners can work with government to oversee the vocational education system. Nevertheless, the proportion of young people entering upper secondary VET has been falling. Sweden has also established an apprenticeship system, but so far the number of young people entering apprenticeship remains very small. Compared with many other countries, upper secondary VET schools, in terms of students enrolled, remain too small to deliver specialised vocational training[43].

For its strategies for regional development, Värmland´s supply and need for skills in relation to smart specialisation was identified in five areas designated areas: Forest-based bioeconomy; digitalisation of welfare services; advanced manufacturing and complex systems; nature, culture and place based digitalised experiences; and systems solutions with photovoltaics. It also covers the horizontal specialisation value-creating services, and a process model for gender integration[44].

Higher education sector

Karlstad University is Värmland's civic university. It hosts education programmes within humanities, social studies, science, technology, teaching, health care and the arts. At present, the university has approximately 16,000 students, in its campuses in Karlstad and Arvika. KAU's research is successful in collaborations in H2020 and with a range of partners from both within the academy and beyond, from major national and international companies, such as Billerud Korsnäs, Stora Enso, and Uddeholm to public bodies, such as Region Värmland. To increase the regional level of education, efforts have been made to develop distance education. There is also collaboration with external researchers, e.g. at Royal Institute of Technology and Chalmers. Karlstad University

[43] Source: OECD Review Vocational Education and Training in Sweden 2019
[44] Source: Skills for Smart Specialisation in Värmland Region. http://norden.diva-portal.org/smash/get/diva2:1463670/FULLTEXT01.pdf

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acts as a hub within a wider network, connecting its own researchers and research groups with collaborators beyond academia.

5.2.3 Research and innovation

Public sector R&I

There are three main clusters in Värmland (Steel and Engineering, ICT, Forest-based Bioeconomy) with a fourth emerging cluster (Tourism), whereby each cluster has its own cluster organisation, namely Steel and Engineering, Compare, Paper Province and Visit Värmland. Innovation platforms and the Innovation Park bring together companies and organisations related to research, innovation and SME development, and the Technical Research Institute of Sweden (RISE) has been established in the region. In all these clusters, Karlstad University is seen as a crucial and competent partner, not only because of its own academic expertise, but also because, as an internationally oriented university, it offers windows and opportunities for interaction with specialists on a global scale. It appears that the Värmland business community is closely interlinked with Karlstad University[45].

Programmes funded by VINNOVA have been vital in building the general eco-system supporting the forest-based Bioeconomy sector in the region combined with large scale demonstrator and test facilities owned by Research institutes such as Innventia/RISE. The DigitalWell Arena is a continuation of the VINNVÄXT initiative DigitalWell, serving industry and public sector organisations with research on developing digital user-friendly welfare services. Initiated by Compare, Region Värmland, Karlstad University, County Administrative Board, Karlstad municipality, and several other local stakeholders from research collaborate on digital health services, health and innovative digital solutions for the industry.

[45] Source: OECD Report Supporting the Contribution of Higher Education Institutions to Regional Development. Peer Review Report Värmland Region.

Industrial R&I

The innovation system is formed around several cluster initiatives, collaborations with regional higher education institutions and innovation platforms. The cluster initiatives are based on cooperation between different actors. Innovation platforms are set up around new business challenges, demanding interaction between different branches and competences. There are several well-established cluster initiatives and innovation platforms. One example is The Paper Province, which has been awarded a VINNVÄXT project (2013-2023, aiming to build an internationally recognized innovation environment in the region, linked to the forest bioeconomy[46].

5.2.4 Digitalisation strategies and status

The Region of Värmland strongly embraced the European Commission´s Research and Innovation Strategies for Smart Specialisation ("RIS3"), also to influence regional and national policies and to facilitate participation in other European-driven programmes such as Interreg, ESF, EJFLU[47], Cosme and Horizon 2020. This is done in concert with Europe 2020, the national innovation strategy, the government's research and innovation proposal, the National Strategy for Regional Growth and Attraction 2015-2020, as well as at the regional level, the Värmland strategy. A key tool for implementing RIS3 is the Academy for Smart Specialisation. It aims to utilise research for the benefit of industry, the County Administration, the Region of Värmland, and the municipalities in Värmland, and to strengthen the research environments in the region[48].

National digitalisation strategy

Sweden is a front-runner in very high capacity connectivity in Europe, but in order to reach its ambitious national broadband targets it needs to address coverage in remote areas. 84% of Swedish households already had access to 100 Mbps speeds in 2018. The goal is by 2020 to reach 95% coverage of 100 Mbps, and by 2025, 99.9% coverage of 100 Mbps and 98% coverage of 1 Gbps (homes passed). To reach these targets, roll-out in remaining sparsely populated areas needs to speed up. For the next 3 years, the Swedish government has

[46] Source: Regional Innovation Monitor.
[47] Europeiska jordbruksfonden för landsbygdsutveckling (European Agricultural Fund for Rural Development)
[48] Source: Academy for S3 https://www.kau.se/en/external-relations/external-relations-university/good-examples/academy-smart-specialisation

allocated SEK 650 million (€61.16 million) for broadband development. Sweden is preparing a new national State aid scheme for the distribution of this funding for the effective deployment of broadband.

Sweden ranks second in connectivity, scoring 64.4, well above the EU average (50.1). Overall take-up of fixed broadband increased from 78% in 2017 to 86% in 2019, which is higher than the EU average of 78%. Fast broadband (NGA) coverage went up from 78% in 2017 to 85% in 2019, close to the EU average of 86%. Sweden has achieved a 66% take-up rate for at least 100 Mbps fixed broadband, almost two and a half times the EU average of 26%. Very high capacity network coverage also increased, reaching 77% (compared to 72% in 2018), exclusively thanks to FTTP networks, and Sweden now ranks eighth at EU level. In 2019, the prices remain close to the EU average and Sweden scores 66 on the broadband price index, compared with the EU average of 64. Take-up of mobile broadband has reached 124 subscriptions per 100 people and is one of the highest in Europe. Average 4G coverage in Sweden was 97% in 2019 up from 96% in 2018, while the European average is 96%[49].

Regional digitalisation strategy

Region Värmland is responsible for all of the county of Värmland's publicly funded regional development, health care, culture, education and public transport. Värmland´s Regional Strategies for Smart Specialisation (“RIS3”) have a strong focus on issues, some of which are directly in line with digitalisation strategies[50]:

Digitalisation of Welfare Services. In actual environments with users, various types of solutions are developed and tested. This results in better and more effective care, education and other social services and ultimately happier, more competent and healthier citizens. Also, companies have access to real development and testing environments, e.g. Nordic Medtest and Experio Lab. A strong ICT cluster brings together businesses and a university (Computer Science at Karlstad University) offering a multi-disciplinary scientific environment permitting the gathering of unique data in nursing, school development, IT and service development.

Advanced Manufacturing and Complex Systems. Energy and resource-efficient systems solutions and components are developed for vehicles, forest industry and renewable energy, energy efficiency and hydrodynamics. Companies are supported in the introduction of advanced manufacturing methods and other key

[49] Source: Digital Economy and Society Index, DESI 2020, Sweden. https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=66932
[50] Source: S3 Platform, https://s3platform.jrc.ec.europa.eu/regions/se311.

enabling technologies which are relevant for existing production. Companies have access to an open development environment, e.g., at the Computer Science Group and the Material and Design Centre at Karlstad University. Through collaboration with Paper Province, there is a special emphasis on products and services in the bioeconomy sector. The regional commitment to photovoltaics also generates new opportunities for innovative engineering products.

Nature, Culture and Place Based Digitalised Experiences. Knowhow, stories and natural values of places using digital technology and media in order to create unique experiences for visitors. Using digital technology, we can enhance the experiences. In order to develop technology and services, research in cultural geography, media/communications, computer science and services are involved, as well as the ICT companies in the Compare cluster, the hospitality and tourism industry.

5.2.5 RRI strategies and measures

Gender equality

The labour market in Värmland is gender-segregated both horizontally and vertically, which means that women and men find themselves in different sectors and industries, and in different positions within one and the same industry or workplace. In the case of business and entrepreneurship, most men in Värmland operate businesses in farming, forestry and fishing, while most women run companies offering cultural and personal services[51].

In 2006, Region Värmland began gathering gender equality statistics for Värmland which gathers the county's six municipalities. The statistics show that the state of gender equality is pretty bleak, and that things have been more or less static in the past five years. For instance, 9.3% of CEOs in Värmland companies are women, and only three out of the 16 municipalities have female mayors, and 21% of senior politicians and officials are women. There are also big wage differences, and on average men earn 8,800 EUR more each year than women. More men than women are unemployed, but 51% of women of foreign heritage are outside of the labour market[52].

[51] Region Värmland, 2015. https://www.kau.se/files/2017-12/Strategy%20Smart%20Specialisation%202015-2020.pdf
[52] Source: Nordic Labour Journal 2017 (http://www.nordiclabourjournal.org/i-fokus/in-focus-2017/women-and-power-in-the-workplace/article.2017-03-02.2484620431)

With regard to policies towards gender integration, the Värmland Region works along the RIS3 strategy. Värmland is the first region in Europe to have conducted a gender analysis study and undertaken a conscious gender-mainstreaming of the strategy for smart specialisation. In this regard, Värmland stands out as a pioneer for gender equality. Analytical methods and mapping procedures have been implemented to raise awareness of the gender equality perspective throughout the innovation and corporate climate in Värmland. Policy analyses and other preparatory studies have been conducted, prioritising efforts to include gender as a variable to be considered in the development of future policies.

5.3 R&I performance in digitalisation

The central part of the mapping of the DigiTeRRI R&I ecosystem in Värmland is to characterize the region with respect to the involved R&I actors and their role in the digitalisation process. We hereby provide quantitative and qualitative analyses of the R&I activities, taking a comparative perspective on the three involved territories, Grand Est, Styria and Värmland. We point out that, due to substantial differences among the territories, a direct comparison of the results, especially a ranking, is often not useful. Nevertheless, we structured the results sections in the same way, so that parallels can be drawn for trans-territorial learning.

The next three sections cover a spectrum of digitalisation activities in Värmland starting from i), scientific research to ii), more application-oriented aspects focusing on knowledge exchange between research and industry, and also take into account, iii), the development of new digital technology.

5.3.1 Creation of scientific knowledge

As described in Section 2.2.3, we use data from the Web of Science database (Clarivate Analytics) to analyse the thematic research activities in Värmland (SE311). The identification and request of a relevant number of scientific articles for each region and their analysis was based on the previous definition of a geographic range corresponding to the regarded region, a certain time period, and a relevant thematic focus. Further on we used the software BibTechMon (Kopcsa and Schiebel 2001) for keyword extraction and for further analysis. Disciplines, authors, affiliations, keywords and references were extracted from the relevant fields of the database.

Geographic range: Relevant publications with at least one author's affiliation from the Värmland region were downloaded.

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Time period: Publications in the time range 2010-2020 were taken into account with a result of 1555 publications on the retrieval day September 1, 2020.

Thematic focus: For further analysis a thematic limitation was made on the basis of Web of Science disciplines. We listed the science disciplines and their numbers of publications and selected core digitalisation relevant disciplines to define the thematic focus. For the analysis of Research Fields no previous thematic focus was applied.

Core digitalisation relevant disciplines

The science categories of WoS allow a first overview about the disciplines of published articles with at least one author from the region. The thematic delimitation was based on Web of Science (WoS) Categories as relevant scientific disciplines. By expert judgement, a set of WoS Categories was selected for Värmland as having a direct relevance for digitalisation. Thus, core digitalisation relevant disciplines for Värmland were identified and ranked according to the number of publications in Table 20. Telecommunications, Computer Sciences (comprising, e.g., many cybersecurity applications), Automation and Control Systems, Radiology, Medical Informatics, and Robotics, were picked for Värmland as digitalisation related disciplines.

Table 20. Scientific publications in digitalisation related disciplines from Värmland (2010-20)

SCIENTIFIC DISCIPLINE	NUMBER OF PUBLICATIONS
Telecommunications	53
Computer Science, Information Systems	44
Computer Science, Theory & Methods	27
Automation & Control Systems	22
Computer Science, Hardware & Architecture	16
Computer Science, Software Engineering	12
Computer Science, Interdisciplinary Applications	11
Radiology, Nuclear Medicine & Medical Imaging	4
Computer Science, Cybernetics	3
Medical Informatics	3
Robotics	2
Computer Science, Artificial Intelligence	1

Source: Web of Science (WoS); data retrieved September 1st, 2020.
Note: Science discipline relates to the WoS Category; Scientific discipline relates to the WoS Category; publications can be assigned to more than one category, leading to multiple counting.

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Digitalisation in the science map of Värmland

Figure 13 shows the network of all Värmland WoS Categories, with embedded digitalisation relevant WoS Categories (blue nodes from Table 20). This network of co-disciplines shows strong research activities in social sciences in the upper left part of the network, with categories such as sociology, communication, economics. Health sciences, with categories such as health policy, sports policy, psychology and psychiatry are located in the lower left part. In the middle of the network public aspects, such as education, transportation, public health, nursing, and also the environmental sciences are found. Biology, ecology, and fisheries are located in the bottom; Materials sciences, engineering, and (bio)chemistry in the lower right side, and the computer sciences, electrical engineering, physics, and mathematics on the top right side of the network.

The computer sciences, mathematics, automation and control systems, robotics, and others strictly related to digitalisation research are marked blue and are found in the top right part of the network. Medical informatics and radiology are located in the health region of the network.

A lot of categories with a political dimension were found in these research activities. As many of them are located in a central position of the network, we can assume that research activities in Värmland integrate political views on a broad range of research topics. The analysis of science activities based on Web of Science categories gives the impression of a research where social, technological, environmental, and political aspects are well-balanced.

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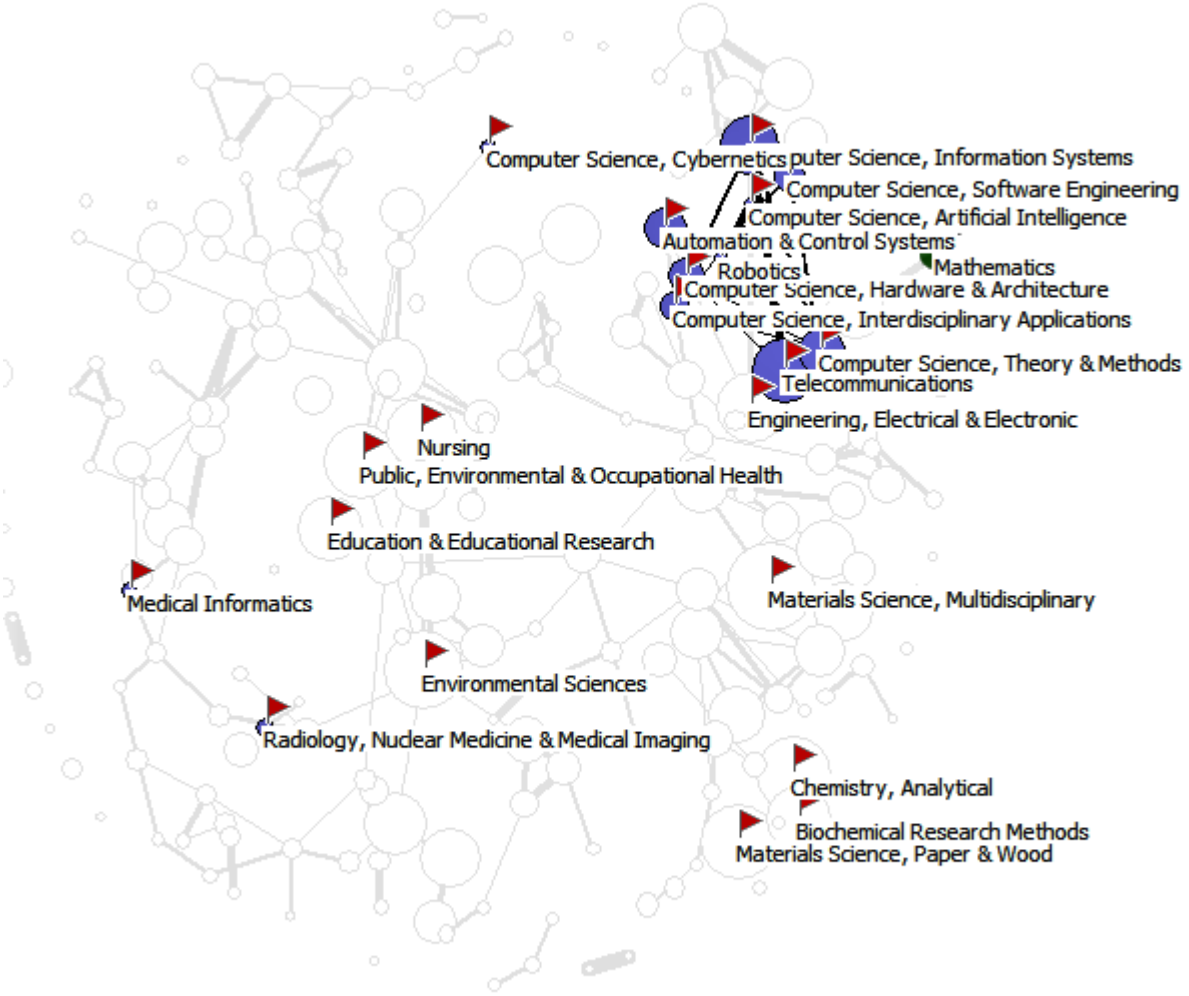

Figure 13. Co-occurrence network of scientific disciplines in publications from Värmland (2010-20)

Source: Web of Science (WoS); publications with at least one author from Värmland; data retrieved September 1st, 2020.
Notes: Scientific discipline relates to WoS Category; node size refers to the number of publications; length of edges relates to the Jaccard-index of co-occurrence. WoS Categories with less than 25 publications are not displayed. WoS Categories directly relevant for digitalisation are marked blue, with red flags and labels. White nodes with red flags mark disciplines with a number of publications 50 or higher, labels are shown for orientation reasons.

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Publication landscape of Värmland

As we are interested in publications that are related to digitalisation, we first calculate clusters of similar publications which we can interpret as related research with a critical mass. The map of bunches of similar publications (“Research Fields”) was drawn as a 3D surface map of the weighted local density of the number of publications (by the Jaccard-Index of links). Hot zones around the peaks were made up of so-called core documents that are highly similar due to a relative high number of common references. In this way, Research Fields were created by co-citation analysis (bibliographic coupling) using giving a similarity-based proximity.

We mapped the complete research activity in which is shown in Figure 14. Research activities are indicated with peaks in the landscape of publications. They correspond to the thematic areas of the overall research in the region. In this study we focused on research activities related to digitalisation which are indicated in green colour in the figure. The relevance for digitalisation was calculated by the co-occurrence of Research Fields with WoS Categories that are highly relevant for digitalisation, see Section 2.2.3 and Table 20. Hereby, a Research Field was defined as relevant for digitalisation if at least one publication was assigned to a digitalisation category.

Figure 14 shows the core Research Fields of the scientific landscape of Värmland. The peak with the highest number of scientific publications and the second highest density of publications (peak) refers to “Business - service-dominant logic and co-creation of value”. The highest peak (which was not rated as in direct relation to digitalisation issues) refers to “Chemistry, Analytical - purification or extraction of chemicals or proteins”, and the third one refers to “Transportation - subjective well-being to travel behaviour”. Other significant (but not directly digitalisation related) peaks refer to: “Marine & Freshwater Biology - freshwater pearl mussel”, “Mathematics - two-dimensional rational conformal field theory”, “Fisheries - fish passage problems in regulated rivers”, and Materials Sciences.

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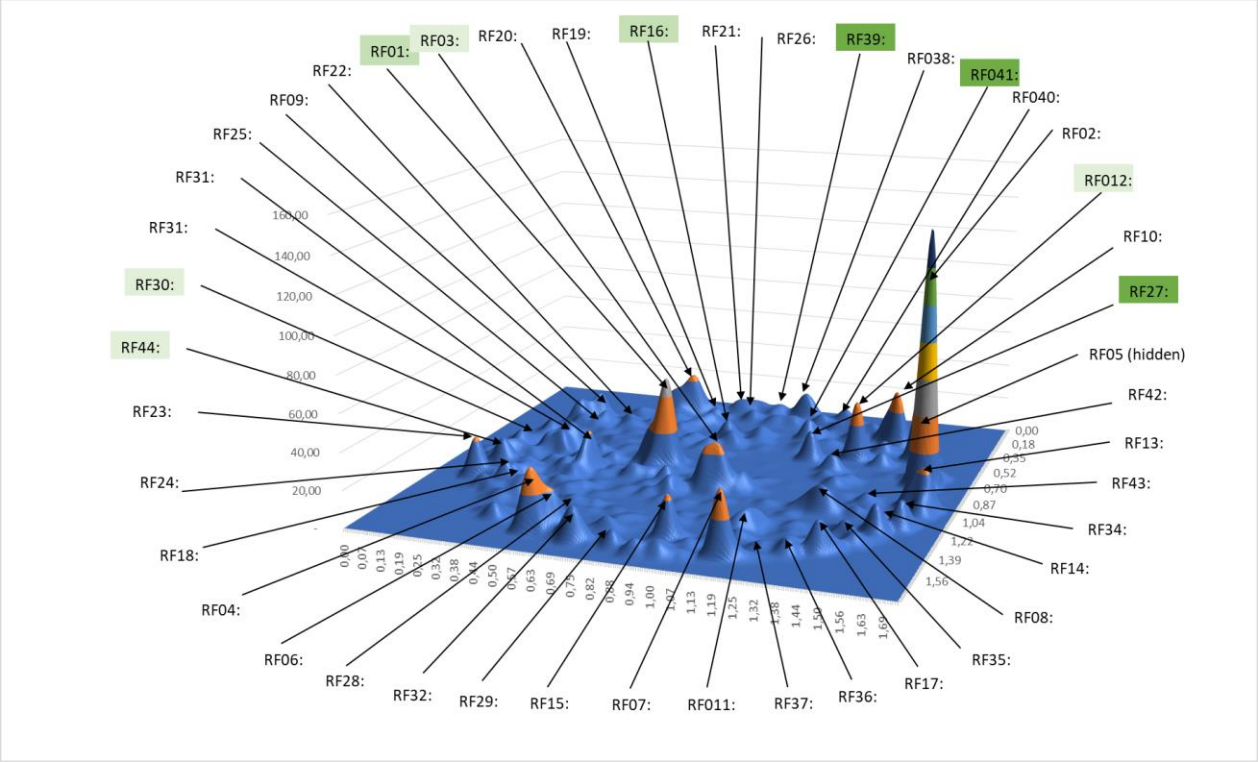

Figure 14. Landscape of Research Fields in Värmland (similar publications in the WoS) (2010-20)

Source: Web of Science (WoS), data retrieved September 1st, 2020.
Note: Map of agglomerations of similar (bibliographically coupled) publications. Proximity is related to the share of joint references, weighted by the number of co-author linkages. Fields with relevance for digitalisation are highlighted: light green: 1 to 5, medium green: 6 to 10 and dark green 10 to 25 publications in digitalisation. Explanation of the labels see Table 21 and Table 32 in the Annex.

Thematic focus of Värmland

In the case of Värmland the regarded time span was broadened to ten years due to the scarcity of identified publications.

Core Research Fields in Värmland (scientific publications clustered by bibliographic coupling) and their number of publication in Web of Science Categories (WC) which were previously defined as highly relevant for digitalisation are listed in Table 21. Main focus of the digitalisation literature of Värmland was found in the field of Computer Science, Information Systems – software defined networks with 37 relevant digitalisation publications. Also, Telecommunications, Automation & Control Systems, were identified as digitalisation Research Fields in Värmland´s publications.

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Table 21. Digitalisation publications in Värmland by Research Field (WoS 2010-20)

RESEARCH FIELD		NUMBER OF PUBLICATIONS
RF39	Computer Science, Information Systems – software defined networks	37
RF41	Telecommunications – Applications and improving the stream control transmission protocol (SCTP)	35
RF27	Automation & Control Systems – errors-variables methods	10
RF01	Business – service-dominant logic and co-creation of value	5
RF16	Communication – online news and social media	4
RF30	Nursing – nurses' competence	2
RF03	Transportation – subjective well-being to travel behaviour	1
RF12	Mathematics – discrete velocity models	1
RF44	Nursing – human dignity	1

Source: Web of Science (WoS), data retrieved September 1st, 2020.

Key actors in scientific publication

Scientific publication in Värmland is concentrated on a limited number of organizations. Apart from Karlstad University, the main location of basic research activity in the region, Karlstad Hospital and the Research Center Karlstad (CTF) contribute to the territory´s publication record.

Table 22. Key organizations from Värmland in digitalisation related scientific publication (2010-20)

ORGANIZATION NAME	NUMBER OF PUBLICATIONS
KARLSTAD UNIVERSITY	83
KARLSTAD HOSP	2
KARLSTAD UNIV	1
RES CTR KARLSTAD (CTF)	1

Source: Web of Science (WoS), data retrieved September 1st, 2020.

5.3.2 Collaborative research and knowledge exchange networks

To analyse knowledge exchange in the R&I ecosystem of Värmland, we draw upon recent and current digitalisation related projects conducted under public funding programs at the regional, national and European levels. Such data are widely used in innovation research since they allow to characterize the institutional composition of the regional R&I ecosystem with very good representativity. First, we choose the European Framework Programme as the most important transnational R&D collaboration initiative, for mainly two reasons.

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First, because it has broad societal objectives and not merely an industry orientation, and second, because it covers international knowledge exchange, which is essential for small open national and even more, regional economies.

The analysis of EU-funded projects (see Chapter 3 for the details of identifying digitalisation-related projects) gives a first insight into the institutional composition of this aspect of the R&I ecosystem in Värmland (Table 23). In total, 6 organisations were and are active in altogether 17 H2020 digitalisation projects (2014 - March 2020). Industry (50% of the participants) accounts for 15% of the project participations. Note, that since two or more organisations may be involved in the same project - which are counted as separate participations – the number of participations is higher than the number of projects (20 participations from Värmland in a total of 16 H2020 projects).

Table 23. Institutional composition of Värmland in H2020 digitalisation projects

ORGANIZATION TYPE	ACTORS		PARTICIPATIONS	
	NUMBER	SHARE	NUMBER	SHARE
Education (EDU)	1	17%	12	60%
Research organization (ROR)	-	-	-	-
Industry (IND)	3	50%	3	15%
Other (OTH)	1	17%	2	10%
Government (GOV)	1	17%	3	15%
Total	6	100%	20	100%

Source: EUPRO (Status March 2020).

The higher education sector in Värmland is represented by only one outstanding institution (Karlstad University), accounting, however, for no less than 60% of all participations from the region. Apart from overall size, the low number of involved organizations from Värmland stems from its specific industry structure and from the absence of research organizations that are specialized on digital technologies and the digital transformation of the R&I ecosystem.

Thematic profile of Värmland´s H2020 digitalisation activities

The digital transformation penetrates all economic and societal activities. To investigate how digitalisation activities in Värmland affect the different sectors of society and industry, we focus on the thematic profile of its involvement in H2020 digitalisation project participations. Hereby, we look at their distribution over the

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H2020 subprogrammes (Thematic Programmes). The most important subprogramme for Värmland is “Industrial leadership”, gathering almost one third of Värmland´s participations (see Table 24), which underlines the strong the awareness of the need for global competitiveness. Furthermore, Värmland is strongly represented in food security with 24% of the participations. Other areas of activity at European level are health, demographic change and well-being, social sciences and security research, with 12%, 12% and 8% respectively. The relative strength of Värmland´s activities in topics of societal relevance highlights the aspiration to use digitalisation as enabling technologies in the existing R&I ecosystem of the region.

Table 24. Värmland´s digitalisation project participations in H2020 sub-programmes

SUBPROGRAMME	PARTICIPATIONS	
	NUMBER	SHARE
Industrial leadership	8	32%
Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy	6	24%
Health, demographic change and well-being	3	12%
Science with and for society	3	12%
Secure societies - Protecting freedom and security of Europe and its citizens	2	8%
Innovation in SMEs	1	4%
Smart, green and integrated transport	1	4%
Europe in a changing world - inclusive, innovative and reflective societies	1	4%
H2020 Total	25	100%

Source: EUPRO
Note: participations are subject to multiple counting due to joint calls of the H2020 subprogrammes.

Key players from Värmland in H2020 digitalisation projects

To complete the institutional analysis of Värmland´s participation in H2020 digitalisation activities presented in the above, we now look at the six H2020 participants from the region. Participation numbers are by majority from the public sector, i.e. from the university, government and a regional cluster organization. Industry firms are only involved in H2020 digitalisation projects through singular participations, as shown in Table 25.

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Table 25. Key organizations from Värmland in H2020 digitalisation projects

ORGANIZATION NAME	TYPE	NUMBER OF PARTICIPATIONS
KARLSTADS UNIVERSITET	EDU	12
Värmlands läns landsting	GOV	3
THE PAPER PROVINCE EKONOMISK FOERENING	OTH	2
CELLCOMB AB	IND	1
NORDIC MEDTEST AB	IND	1
Rolls-Royce AB	IND	1

Source: EUPRO

Värmland´s digitalisation networks of in EU-H2020

Due to the mentioned pervasiveness of digitalisation in the whole economy, the term itself is rarely used in specific R&I activities. Identification and analysis of such activities has therefore to rely on more specific categories: We use the distinction between pure development and the application of digital technologies in R&I projects as an analytic device. Therefore, we associate the development of new technologies, methods and concepts with “development-oriented” projects (as, for instance, with data stream analysis), and projects that are deeply rooted in application fields (e.g., digital factories or rail operations) are rated as “application-oriented” projects. For this purpose we use specific thematic keywords that are available for each H2020 project, and group these keywords into two disjoint sets, namely development-oriented and application-oriented keywords (for the complete lists of keywords, see Table 36 and Table 37 in the Annex). Using these two sets of keywords, we obtain two (non-disjoint sets) of projects which have development and/or application aspects.

In Värmland, all 17 digitalisation projects in H2020 are application-oriented, while 7 of these projects (41%) exhibit also development aspects. We do not find development-only projects, which again reflects the strong role of digitalisation as an enabler for the R&I ecosystem in Värmland.

Development project network of Värmland

In the 7 development-oriented H2020 digitalisation projects with participants from Värmland, partners from 24 countries are involved, reflecting the international orientation of the European Framework Programme. Since we are interested in the knowledge exchange potentials, we look at how participations from Värmland are linked with other Swedish and international partners in these projects applying network visualization techniques.

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In the resulting network diagram (see Figure 15), the nodes represent project participations according to organization type and country involved, whereby participations from Värmland itself are separated from the rest of Sweden. Thus, for instance, an industry firm from Gävleborgs län in Sweden contributes to SE-IND, a university from the United Kingdom comes in as UK-EDU, and a research organization from Norway counts as NO-ROR, while a governmental institution from Värmland is labelled SE311-GOV. This leads to a network with 55 nodes.

What we find in development-oriented digitalisation projects of Värmland is an industry-led network, with Spanish firms (11 participations), together with Italian and French industry firms, being the most active partners. The network is, however, not strongly centralized, and a lot of university and research organization partners from the EU and Associated countries are involved in the loosely knit network centre. The international outreach of Värmland´s development collaboration seems to be basically limited to Europe.

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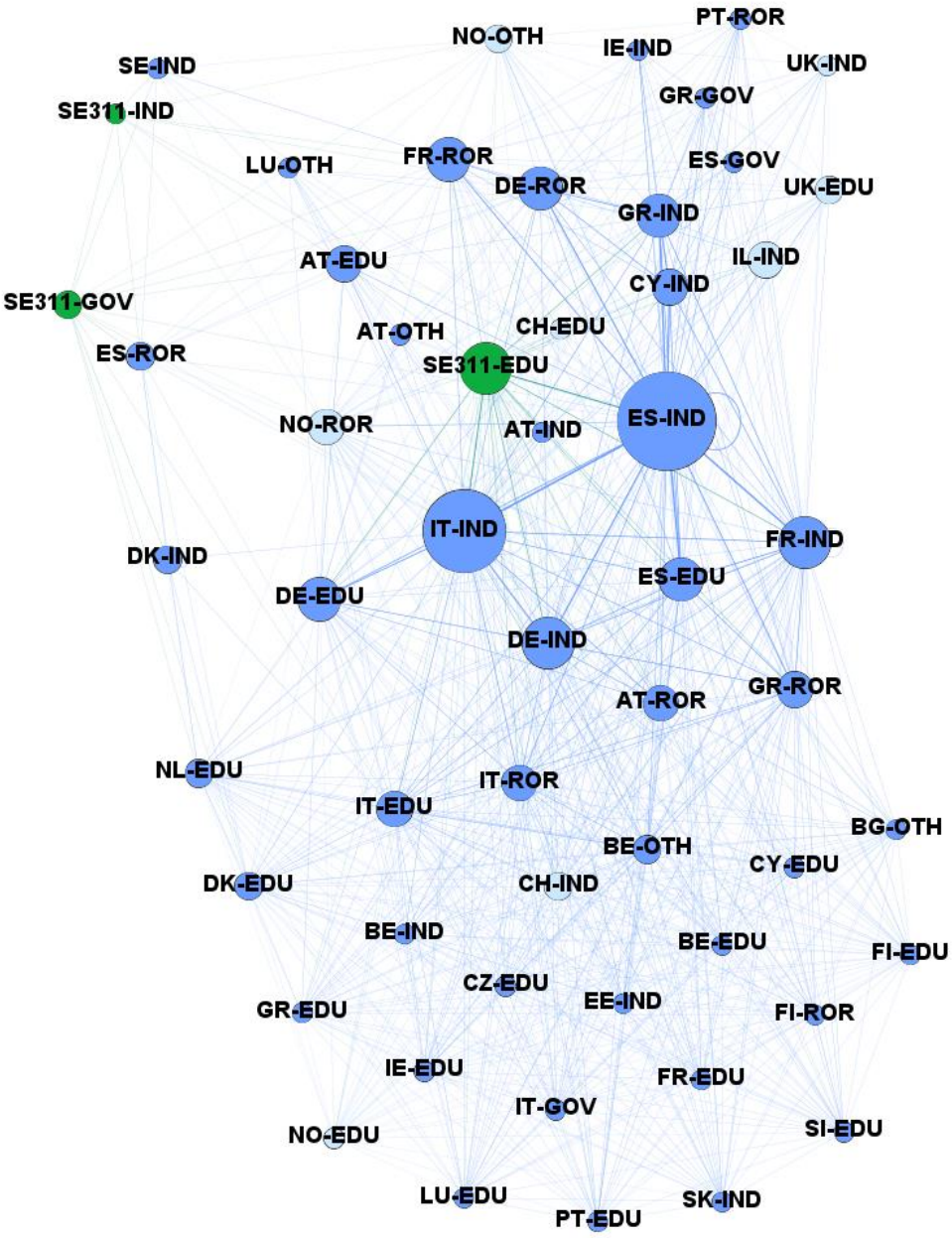

Figure 15. H2020 participation network of Värmland in development-oriented digitalisation projects

Source: EUPRO (Status March 2020).

Note: Nodes refer to partner country and type of organizations, node size corresponds to the number of participations from this group ($1 \leq n \leq n_{max} = 11$). Links refer to joint project participations, node distance corresponds to the relative frequency of joint project participations. Värmland is distinguished (nodes in green and labels SE311-x) from the rest of Sweden (labels SE-x). For organization type codes, country groups (colour of nodes) and country codes, see Table 34 and Table 35 in the Annex.

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The position of Värmland is mainly determined by the role of Karlstad University (SE311-EDU), which is directly embedded in the central area of the collaboration network, and closely linked with the main partners in Spanish and Italian industry, but also close to industry from Austria and Cyprus, Norwegian research organizations and Swiss universities. Interestingly, Värmland´s industry is only loosely connected through H2020, as its location at the periphery of the network indicates.

Application project network of Värmland

In Värmland, we identify17 application-oriented digitalisation projects, which at the same time comprise all digitalisation projects of the region in H2020. Thus, we have a much larger set of application-oriented projects than in development; in fact, it is this network where we observe all partners from Värmland and the full institutional and geographical outreach of their activities in H2020. Collaboration partners are from 32 countries worldwide, including a small number of non-European countries, both overseas High-income countries and International Cooperation Partner Countries of H2020.

Applying network visualization techniques, we obtain the network diagram presented in Figure 16. Hereby, nodes stand for project participations from a certain organization type and country, and Värmland is separated from the rest of Sweden, to carve out the region´s position in a more detailed way. The network consists of 89 nodes, with the largest node representing 16 project participations together with organizations from Värmland (industry firms from Italy, IT-IND). To discuss the knowledge exchange potentials of Värmland, we look at the structure of its collaboration network, how their organizations are linked with other Swedish and international partners in these application-oriented digitalisation projects in H2020.

What we find is a larger, more heterogeneous and dispersed network than in the case of development projects, especially with respect to international involvement. A large central cluster of organizations forms the main area around the main industrial players from Italy, Spain, France, Germany and the Netherlands. However, the composition of this cluster is pretty heterogeneous and combines also universities and research organizations from all over Europe and, also US and Australian universities and research organizations. We also identify two separated clusters, mainly due to collaborations among governmental and other organizations which are mutually interlinked but only loosely connected with the main network cluster of industrially oriented participations.

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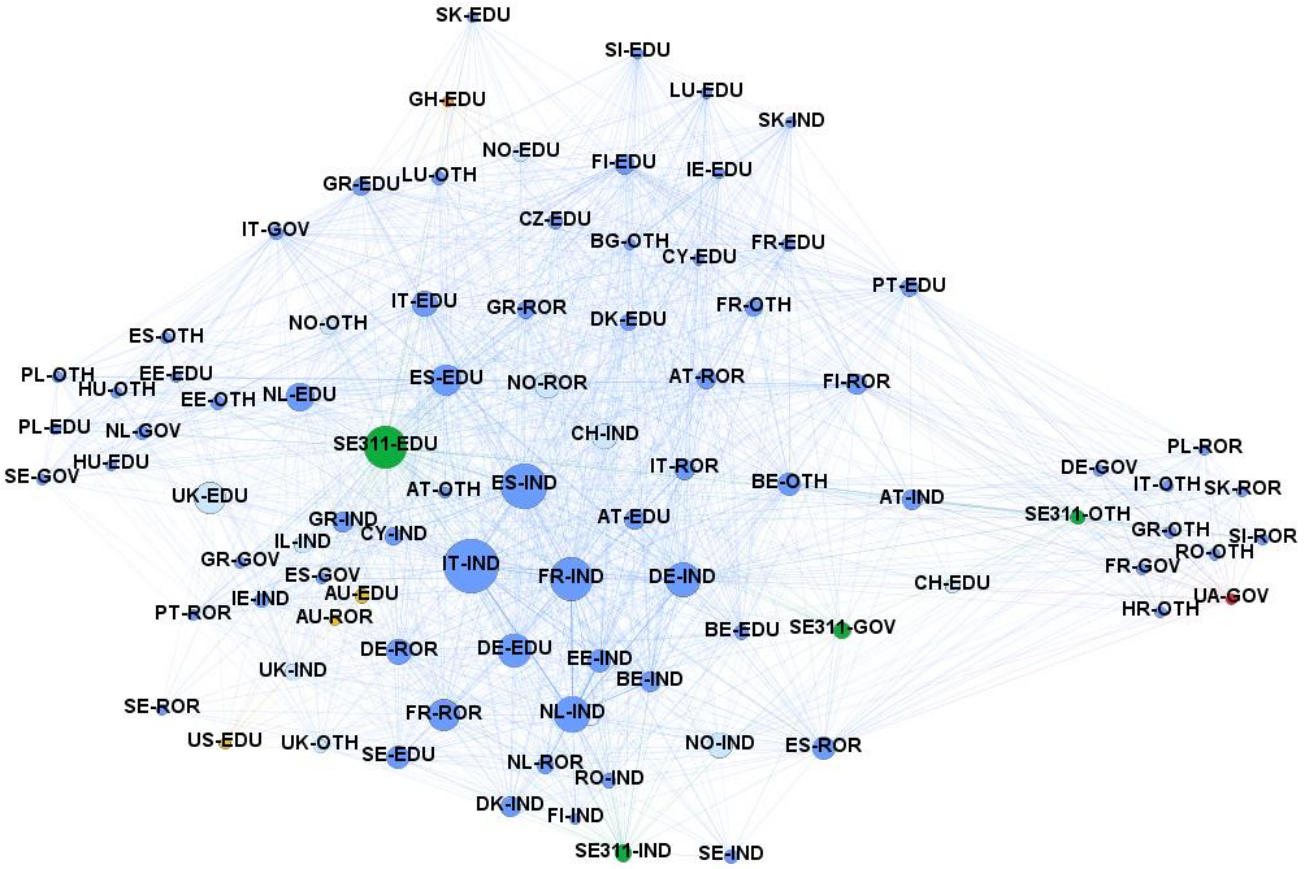

Figure 16. H2020 participation network of Värmland in application-oriented digitalisation projects

Note: Nodes refer to partner country and type of organizations, node size corresponds to the number of participations from this group ($1 \leq n \leq n_{max} = 16$). Links refer to joint project participations, node distance corresponds to the relative frequency of joint project participations. Värmland is distinguished (nodes in green and labels SE311-x) from the rest of Sweden (labels SE-x). For organization type codes, country groups (colour of nodes) and country codes, see Table 34 and Table 35 in the Annex.

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The positioning of organizations from Värmland in the application network is strongly determined by the main player, Karlstad University (SE311-EDU), which, by its dominance in terms of participations, constitutes the main cluster. It is both linked with Italian, Spanish and several less prominent industry partner countries, and universities from Spain, the Netherlands and the UK. It also constitutes a network area of heterogeneous institutional partnerships with a range of countries within and outside Europe, comprising, e.g., the Greek governmental organisation, Australian universities, other organizations from Estonia and industry from Cyprus. Other organizations from Värmland play a less central role in the network – they are positioned at the periphery of the main cluster or in detached clusters of Värmland´s application-oriented digitalisation network in H2020.

Digitalisation in regional funding activities in Värmland

Region Värmland has implemented a regional innovation strategy directly linked to the Smart Specialization Strategy of the European Union (RIS3). In the period 2015-2020, a total of 57 initiatives have been conducted or started in Värmland under a funding mix comprising regional, national, community, European (ERDF, Interreg) and private funds. These initiatives are implemented by 17 different organizations (*"Projektägare"*) and operate in altogether 9 regions in Sweden and bordering Norway. Figure 17 shows a network diagram of these initiatives, whereby we depict the managing organizations of these initiatives and the regions in which they operate. Note that the presented network does not exhibit the financial aspects of these RIS3 projects, nor their beneficiaries. Thus, it reflects the activities in the territory from an institutional and regional perspective.

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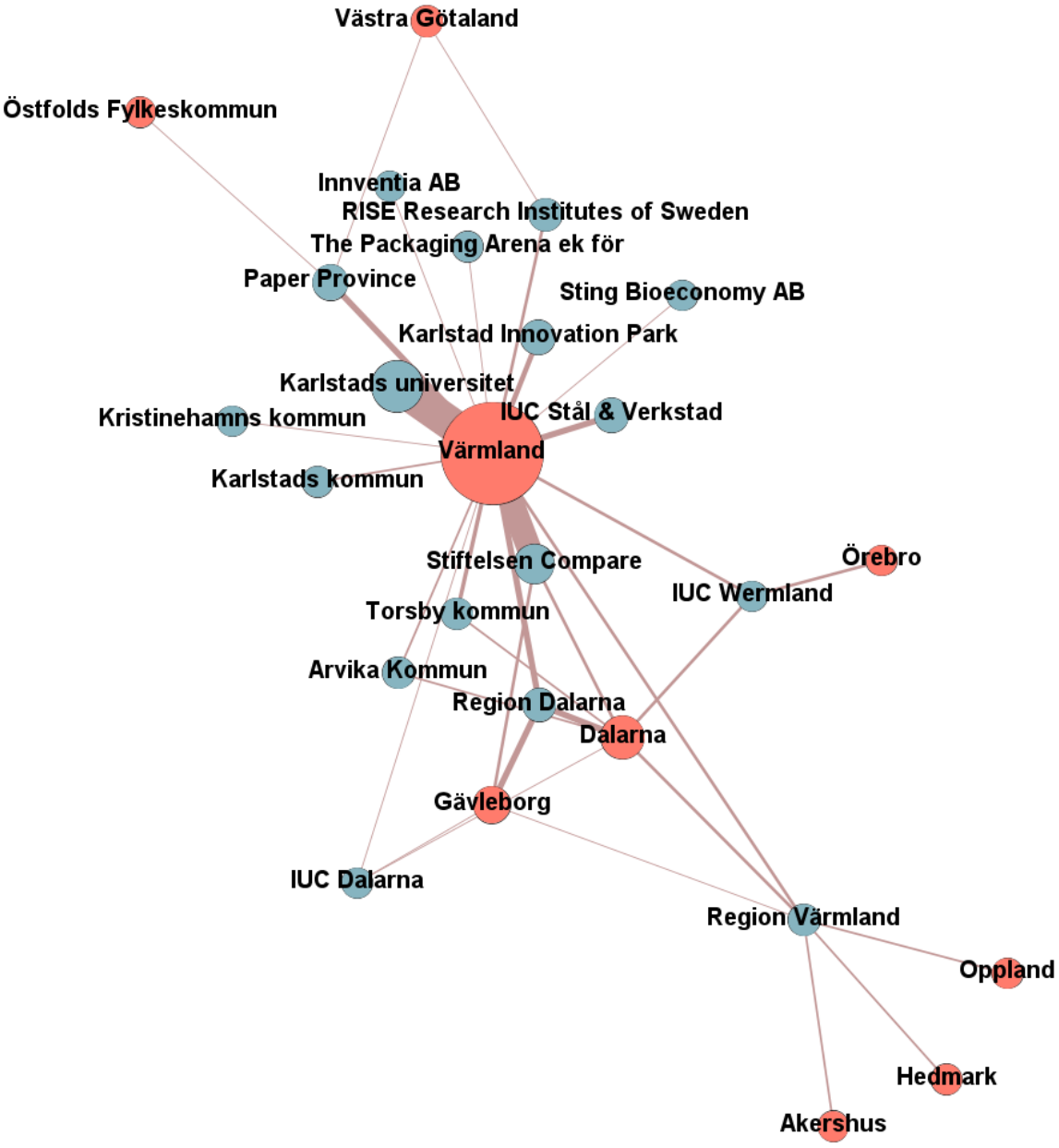

Figure 17. Network of RIS3 initiatives on digitalisation in Värmland (2015-2020)

Source: RIS3 Database (Region Värmland/VINNOVA).

Note: Red nodes denote the administrative regions where the RIS3 initiatives operate, blue nodes denote the organizations responsible for their implementation; node size refers to the number of initiatives. Links denote the availability of an organization´s initiatives in a region; link thickness refers to a combination of number and relevance of these initiatives for digitalisation; a shorter link denotes a higher relative exclusiveness of an organization´s funding activities in the connected region.

By definition of our thematic focus, Figure 17 shows that all managing organizations are operating in Värmland County, some of them additionally also in 4 neighbouring Swedish regions and 4 Norwegian regions. The most important operative organization in the RIS3 activities is Karlstad University, implementing 17 initiatives in Värmland, of which 5 are dedicated digitalisation measures, 6 comprise substantial digitalisation aspects, and 6 are projects in wider application fields of digitalisation. Stilftesen Compare manages 8 initiatives in Värmland with digitalisation at its core, and one relating also to Dalarna, Gävleborg and Örebro Counties. Paper Province is the manager of further 5 initiatives, and several organizations are handling projects with an outreach beyond Värmland. For instance, Region Värmland and Paper province implement measures including Norwegian regions Østfold[53], Akershus, Hedmark and Oppland.

5.3.3 Development and application of digital technologies

The analysis of patents allows for characterizing important aspects of a territorial R&I ecosystem, namely the development of new technology and its economic exploitation. Based on the International Patent Classification (IPC), we focus on those technology classes which are especially relevant for digitalisation – information and communication technologies (ICT) – using the standard OECD classification. It assigns patent subclasses (IPC-3-digit codes) to so-called ICT fields (see Table 33). Since each patent is assigned to one or multiple patent classes, this kind of data is suited to gain insights into the substance of new inventions, both regarding ICT-internal distribution of technologies, and with respect to their influence on non-ICT technologies, and thus the whole technological variety of the R&I ecosystem.

Patents in Information and Communication Technologies (ICT)

Retrieving PCT patents from the PATSTAT database with applicants from Värmland (NUTS code SE311) in the period 2014-2018, we identify a total of 260 international patents (PCT-numbers). 25% of those are assigned to at least one ICT field, yielding a set of 66 ICT patents which was selected for further analysis, involving 24 organizations from Värmland as applicants. Further analysis is based on fractional counting, i.e., in case a patent is assigned to more than one patent class, these patent classes receive respective shares of the patent

[53] Østfold is a territory and former province in south-eastern Norway that became part of the new province of Viken in the course of the 2020 regional reform.

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count. Mutatis mutandis is applied to multiple applicants. In this way, we obtain weighted numbers for better comparison of the subsectors.

In total, Värmland accounts for 29.6 ICT patents (fractional counting) in the period 2014-18, representing 17.1% of all patenting activity (173.1 patents) in Värmland (Table 26). This is a medium share as compared with the other two regions in DigiTeRRI, Styria and Grand Est. Contrasting the total number of 66 ICT patents (full count) with 29.6 by fractional counting, reveals the strong generic nature of ICT development in Värmland: 55% of the average ICT patent is associated with non-ICT classes. Within ICT fields, the lion share of assigned patent classes go to “Telecommunications” (15.1 patents), followed by “Other ICT”, comprising measurements and semiconductor technologies (7.4 patents). “Computers, office machinery” accounts for 5.2 patents and less important for Värmland is the ICT field “Consumer electronics”, comprising only 1.8 patents during the covered application period (1.1% of all patents).

Table 26. ICT patents from Värmland by subclasses (2014-18)

ICT SUBCLASS	PATENTS		
	NUMBER	SHARE	RTA
Computers, office machinery	5.2	3.0%	0.47
Consumer electronics	1.8	1.1%	0.68
Other ICT	7.4	4.3%	0.46
Telecommunications	15.1	8.7%	1.15
Total ICT patents	29.6	17.1%	0.69
Total patents	173.1	100%	1

Source: PATSTAT
Note: Calculations based on fractional counting

The Revealed Technological Advantage (RTA) is a well-established measure of relative technological specialization of a territorial unit within a larger context; it can be measured in terms of patents (for details of the methodology see Chapter 2). Table 26 gives the RTA values for Värmland, relating its ICT patents to the European level (EU28 plus Switzerland and Norway). The results show a general weakness of Värmland in ICT, but within ICT, remarkable overrepresentation of “Telecommunications” in Värmland (RTA = 1.15) as compared with the European average (RTA = 1). This strength in telecommunication technology, resonates with the outstanding role of telecommunications in Sweden as a whole (RTA = 4.3), but has obviously little effect on the other ICT fields in Värmland: “Consumer electronics” achieves only an RTA value of 0.69, while “Computers, office machinery” and “Other ICT” are strongly underrepresented as compared with the European context.

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Key patenting actors in ICT

Key actors in digitalisation-related patenting in Värmland are companies, whereby one global player stands out of the group of applicants and is responsible for the strong concentration of patenting activity in telecommunications. Thus, three of the Top 5 applicants are from the telecommunications sector (Ericsson, Intel and Icomera) and one from automotive (Sem) and one from the pulp and paper industry (BTG). Other applicants are mostly local enterprises and individuals (see Table 27). The public sector organizations do not play a role in this field of technology.

Table 27. Top 5 applicants for ICT patents in Värmland (2014-18)

ORGANIZATION NAME	NUMBER OF PATENTS
Telefonaktiebolaget LM Ericsson (publ)	33
Icomera AB	7
Intel IP Corporation	3
Sem AB	3
BTG Instruments AB	2

Source: PATSTAT

The concentration of ICT patent applicants is highest in Värmland among the territories involved in DigiTeRRI: Here, the Top 5 applicants jointly amount to no less than 73% of the ICT patents. This result may indicate that the presence of large ICT multinationals does not necessarily have a high impact on local technology development, and may remain disconnected from other technology fields in the region, especially if the general level of ICT activity at the national level is high and acts at a global scale.

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CHAPTER 6: CONCLUSIONS AND OUTLOOK

This report characterizes the status of the R&I ecosystems of Grand Est, Styria and Värmland with a focus on digitalisation, analysing scientific, technological and organizational characteristics. Knowledge exchange networks within the regions and beyond are identified, along with identifying the key actors in collaborative projects, patenting and scientific publishing. The analysis for the territories was done separately without mutual references and direct comparisons. Nevertheless, the methodological approach was the same for all territories, so that we are able to draw general conclusions from the three analysed cases.

- **Digitalisation is a major concern in the three territories**. The three regions are characterized by traditional manufacturing and processes industries like steel, wood and paper as well as mechanical engineering, especially automotive, rolling stock and aerospace supply, with an acknowledged need to catch up in the digital transformation process. Typically, the development of ICT technologies is underrepresented in the territories (an exception is Styria due to its strong semiconductor industry). Generally, the focus is on the enabling role of digital technologies for innovation in the existing sectors.
- **The stakeholder groups driving digitalisation can be different**. Although digitalisation activities are by nature industry dominated, only Styria´s and Grand Est´s initiatives are also mainly driven by companies and their focus on competitiveness, while Värmland shows a dominant role of the university. Here, activities with a broad societal and economic impact represent the majority of initiatives.
- **Clustering and other forms of partnership are established measures**. From a regional innovation perspective, it makes sense to foster local clustering of strengths, which is a core part of the policy strategies and already widely deployed in the three territories. International networks are abundant, especially in the application of digital technologies where R&I collaborations with global reach are not the exception.
- **The link between national and regional institutions is a major challenge**. The degree of independence of the regional government in regional innovation policy is quite different in the three territories. While the European Union has successfully introduced flexibility at the regional level with its Smart Specialization approach, the institutional setup in the countries, for instance in innovation, education or social policies is largely governed by the national level, which may lead to inefficiencies regarding the advancement of RRI aspects during the digital transformation of the territories.

The results are intended to support the interactive stakeholder processes in the territories (i.e. the visioning and roadmapping) in the subsequent work packages of the DigiTeRRI project. In particular, the key actor lists may serve as a starting point for the selection of a representative set of stakeholders considering the heterogeneity and uniqueness of each territory. Generally, the results are able to support cross-territorial learning in the wider

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local communities. Specifically, the report will serve as an input for Work Package 5 – the monitoring of the roadmap implementation activities. Building on data from existing databases and reports, this study is complementary to own empirical research done in DigiTeRRI, focusing on digitalization practices in the territories through a survey approach (see Deliverable D2.4, Boly et al. 2020).

In methodological terms, the report may also pave the way for the development of a generalized empirical framework that can be used to characterize territorial R&I ecosystems in the future, dedicated such with a sectoral focus to support smart specialization strategies.

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ACKNOWLEDGMENTS

The authors owe special credits to Helen Vogelmann and Anders Olsson (Region Värmland), for the provision of regional R&I project data and their great support, Lundin Reine (Uddeholm) and Brigitte Kriszt (MUL) for their helpful advice and inputs. Great thanks also go to the reviewers of this report, Helen Vogelmann (Region Värmland), Vincent Boly (UL), and Jens Ørding Hansen (NRI) for additional comments and inputs.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 873010.

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ANNEX

Table 28. Geographical delineation of the three territories included in DigiTeRRI

LEVEL	RÉGION GRAND EST	STYRIA	VÄRMLAND
NUTS1	FRF Grand Est		
NUTS2	FRF1 Alsace FRF2 Champagne-Ardenne FRF3 Lorraine	AT22 Styria	
NUTS3	FRF11 Bas-Rhin FRF12 Haut-Rhin FRF21 Ardennes FRF22 Aube FRF23 Marne FRF24 Haute Marne FRF31 Meurthe-et-Moselle FRF32 Meuse FRF33 Moselle FRF34 Vosges	AT221 Graz AT222 Liezen AT223 Östliche Obersteiermark AT224 Oststeiermark AT225 West- und Südsteiermark AT226 Westliche Obersteiermark	SE311 Värmlands län

Note: NUTS classification according to the version of 13 Nov 2019 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02003R1059-20191113)

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Table 29. Categories of digitalisation-related scientific publications in Web of Science (WoS)

WoS CATEGORIES				
allergy	computer science interdisciplinary applications	engineering manufacturing	immunology	public administration
automation control systems	computer science software engineering	engineering multidisciplinary	information science library science	public environmental occupational health
business	Computer Science Theory Methods	environmental sciences	instruments instrumentation	regional urban planning
business finance	construction building technology	ethics	material science multidisciplinary	remote sensing
communication	education educational research	genetics heredity	Materials science ceramics	robotics
computer science artificial intelligence	energy fuels	green sustainable science technology	mathematics applied	social sciences interdisciplinary
computer science cybernetics	engineering biomedical	health care sciences services	medical informatics	social sciences mathematical methods
computer science hardware architecture	Engineering electrical electronic	hospitality leisure sport tourism	metallurgy metallurgical engineering	telecommunications
computer Science Information Systems	engineering industrial	imaging science photographic technology	operations research management science	transportation science technology

Source: www.clarivate.com

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Table 30. Research Fields in Grand Est by number of WoS publications (2018-2020)

RESEARCH FIELD	NUMBER OF PUBLICATIONS	
	ALL	IN DIGITALISATION
RF01: Materials Science, Multidisciplinary - chrystal plasticity	88	2
RF02: Chemistry, Multidisciplinary - Graphene, 2D materials, carbon nanomaterials	68	2
RF03: Chemistry, Physical - porous adsorbens, density functional theory	89	0
RF04: Chemistry, Physical; Physics, Atomic, Molecular & Chemical - quinoxalinone	69	0
RF05: Chemistry, Multidisciplinary - self-sorting, dynamic chemistry	22	0
RF06: Optics - light matter vibrational strong coupling	30	1
RF07: Physics, Applied - acoustic metasurfaces and specifically designed materials	22	0
RF08: Physics, Nuclear - ALICE, heavy ion experiments	128	1
RF09: Astronomy & Astrophysics - Gaia Data Release 2, galaxies	167	3
RF10: Automation & Control Systems - nonlinear networked control systems	54	44
RF11: Optics - photonic information processing	35	10
RF12: Optics - diagnostics with quantum dots (QDs)	25	0
RF13: Chemistry, Physical - surface chemistry for multifunctional polymer coatings	38	0
RF14: Polymer Science - 3D printing, photopolymerization reactions	66	0
RF15: Materials Science, Coatings & Films - nanocomposite coatings, epoxy	41	0
RF16: Cardiac & Cardiovascular Systems - acute heart failure, drug treatment	73	0
RF17: Soil Science - agromining	37	0
RF18: Neurosciences - rapid individual face perception	27	6
RF19: Forestry - drought, forest growth dynamics	69	0
RF20: Parasitology - Cystic echinococcosis, Echinococcus granulosus sensu lato	28	0
RF21: Gastroenterology & Hepatology - Hepatitis C Virus in Liver Pathogenesis	44	0
RF22: Surgery - hand surgery, scapholunate	21	2
RF23: Biochemistry & Molecular Biology - molecular graphics applications, model building, macromolecules	46	0

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RF24: Infectious Diseases - Lyme borreliosis	19	0
not assigned	6402	758
all publications	7708	836

Source: Web of Science (WoS), data retrieved on August 17th, 2020.
Notes: From all 7958 publications 7708 could be considered because of the availability of a reference list. 6402 publications were not identified as part of any of the detected Research Fields.

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Table 31. Research Fields in Styria by number of WoS publications (2018-2020)

RESEARCH FIELD	NUMBER OF PUBLICATIONS	
	ALL	IN DIGITALISATION
RF01: Materials Science- ab initio calculations, DFT, visualisations	140	1
RF02: Astronomy and Astrophysics - planets and satellites	96	
RF03: Astronomy and Astrophysics - sun	49	
RF04: Materials Science, multidisciplinary - Metallic glasses	44	
RF05: Materials Science, multidisciplinary - deformation nanocristalline	55	
RF06: Chemistry, inorganic and nuclear - Crystal structure	41	
RF07: Physics, Particles and Fields - Gauge theories	32	1
RF08: Chemistry, physical and Material Science: Batteries - Ionic conductivity	29	1
RF09: Mathematics: Set of lengths	21	
RF10: Nanoscience and Nanotechnology - Other Topics - Materials - 3D nanoprinting	13	
RF11: Chemistry, multidisciplinary - continuous flow	40	
RF12: Endocrinology & Metabolism - pediatric pulmonary hypertension	19	
RF13: Plant Sciences - hyacinthaceae homoisoflavonoids	15	
RF14: Environmental Sciences & Ecology - Arsenic species	21	1
RF15: Mathematics, applied - Image reconstruction	32	25
RF16: Astronomy and Astrophysics - structure constants - laser-generated spectra	51	2
RF17: Materials Science - fatigue strength assessment	26	
RF18: Physics, Particles and Fields- quantum chromodynamics (QCD) - bearing materials	18	
RF19: Materials Science, multidisciplinary - selective laser melting	31	
RF20: Geosciences, multidisciplinary - Biomarkers petrography	31	
RF21: Neurosciences - disgust - skin picking disorder	22	6
RF22: Mathematics - Giant Component of Random Hypergraphs	14	6
RF23: Microbiology - Microbiota research	26	
RF24: Biochemistry & Molecular Biology - Molecular Evolutionary Genetics Analysis - Molecular Basis of Disease	46	
RF25: Energy and Fuels - Computational fluid dynamics	26	
RF26: Mechanics - anisotropic hyperelastic materials	24	
RF27: Geochemistry & Geophysics - Calcite growth	20	

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RF28: Nutrition and Dietics - Effects of Vitamin D supplementation	15	
RF29: Biotechnology & Applied Microbiology - Biodegradable and Biocompatible Polyhydroxy-alkanoates (PHA)	12	
RF30: Geosciences, multidisciplinary - Evolution of rocks	28	
RF31: Chemistry, physical - Biocatalysis	76	1
RF32: Neurosciences - creative cognition	17	8
Not assigned	5227	544
all publications	6357	596

Source: Web of Science (WoS), data retrieved on July 24th, 2020.
Notes: All 6357 publications could be considered because of the availability of a reference list. 5227 publications were not identified as part of any of the detected Research Fields.

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Table 32. Research Fields in Värmland by number of WoS publications (2010-2020)

RESEARCH FIELD	NUMBER OF PUBLICATIONS	
	ALL	IN DIGITALISATION
RF01: Business - service-dominant logic and co-creation of value	78	5
RF02: Chemistry, Analytical - purification or extraction of chemicals or proteins	65	0
RF03: Transportation - subjective well-being to travel behaviour	54	1
RF04: Marine & Freshwater Biology - freshwater pearl mussel	15	0
RF05: Mathematics - two-dimensional rational conformal field theory	33	0
RF06: Fisheries - fish passage problems in regulated rivers	23	0
RF07: Materials Science, Multidisciplinary - lhigh performance solar cells	30	0
RF08: Materials Science, Paper & Wood - biobased packaging materials	36	0
RF09: Public, Environmental & Occupational Health -early life exposure during pregnancy and infancy to environmental factors	15	0
RF10: Astronomy & Astrophysics - dynamical systems in cosmology	25	0
RF11: Engineering, Chemical - biomass pellets	24	0
RF12: Mathematics - discrete velocity models	13	1
RF13: Mathematics - Hardy-type operators	29	0
RF14: Engineering, Mechanical - tribology	11	0
RF15: Engineering, Chemical - dewatering of paper	10	0
RF16: Communication - online news and social media	40	4
RF17: Physics, Condensed Matter - perylene tetracarboxylic dianhydride (PTCDI) on metal	18	0
RF18: Psychology, Clinical - stress management	45	0
RF19: Education & Educational Research - multiple historical models in school textbooks	13	0
RF20: Public, Environmental & Occupational Health - Swedish National Inpatient Register (IPR) as a source of data	36	0
RF21: Physics, Applied - carbon nanotubes	19	0
RF22: Education & Educational Research - conversation analysis in education	14	0
RF23: Public, Environmental & Occupational Health - health research using the Rasch model	19	0

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RF24: Environmental Studies - education for sustainable developent in Sweden	16	0
RF25: Psychiatry - Asberger syndrome and schizophrenia	14	0
RF26: Engineering, Mechanical - very high cycle fatigue	7	0
RF27: Automation & Control Systems - errors-variables methods	11	10
RF28: Environmental Sciences - climate change biodiversity conservation	24	0
RF29: Ecology - animal migration, migratory propensity	6	0
RF30: Nursing - nurses' competence	30	2
RF31: Substance Abuse - novel psychoaktive substances	29	0
RF32: Marine & Freshwater Biology - Homeostatic Behavioural Responses in a Changing Environment	19	0
RF33: Nursing - nurse students	21	0
RF34: Materials Science, Multidisciplinary - selective laser melting	15	0
RF35: Materials Science, Paper & Wood - lignin revovery	15	0
RF36: Materials Science, Paper & Wood - cellulose dissolution	8	0
RF37: Metallurgy & Metallurgical Engineering - complex deoxidation	12	0
RF38: Physics, Applied - solar cell processing	14	0
RF39: Computer Science, Information Systems - software defined networks	15	37
RF40: Materials Science, Multidisciplinary - elastic properties of ferromagnetic	8	0
RF41: Telecommunications - Applications and improving the stream control transmission protocol (SCTP)	19	35
RF42: Materials Science, Multidisciplinary - machining with mould steel	8	0
RF43: Chemistry, Physical - martensictic stainless steel	8	0
RF44: Nursing - human dignity	35	1
Not assigned	555	102
All publications	1554	198

Source: Web of Science (WoS), data retrieved September 1st, 2020.
Notes: From all 1555 publications 1554 could be considered because of the availability of a reference list. 555 publications were not identified as part of the detected Research Fields.

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Table 33. ICT patent classes used for identifying digitalisation patents

IPC CODE	DESCRIPTION
Telecommunications	
G01S	Radio direction-finding; Radio navigation; etc.
G08C	Transmission systems for measured values, control or similar signals
G09C	Ciphering or deciphering apparatus for cryptographic or other purposes involving the need for secrecy
H01P	Waveguides; resonators, lines or other devices of the waveguide type
H01Q	Aerials
H01S3	Lasers
H01S5	Semiconductor lasers
H03B	Generation of oscillations
H03C	Modulation
H03D	Demodulation or transference of modulation from one carrier to another
H03H	Impedance networks, e.g. resonant circuits; resonators
H03M	Coding, decoding or code conversion, in general
H04B	Transmission
H04J	Multiplex communication
H04K	Secret communication; jamming of communication
H04L	Transmission of digital information
H04M	Telephonic communication
H04Q	Selecting
Consumer electronics	
G11B	Information storage based on relative movement between record carrier and transducer
H03F	Amplifiers
H03G	Control of amplification
H03J	Tuning resonant circuits; selecting resonant circuits
H04H	Broadcast communication
H04N	Pictorial communication
H04R	Loudspeakers, microphones, gramophone pick-ups or like acoustic electromechanical transducers, etc.
H04S	Stereophonic systems
Computers and Office Machinery	
B07C	Postal sorting
B41J	Typewriters; selective printing mechanisms
B41K	Stamps; stamping or numbering apparatus or devices
G02F	Devices or arrangements, the optical operation of which is modified by changing the optical properties
G03G	Electrography; electrophotography; magnetography
G05F	Systems for regulating electric or magnetic variables
G06	Computing; calculating; counting
G07	Checking-devices

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G09G	Arrangements or circuits for control of indicating devices using static means to present variable information
G10L	Speech analysis or synthesis; speech recognition; speech or voice processing; etc.
G11C	Static stores
H03K	Pulse technique
H03L	Automatic control, starting, synchronisation, or stabilisation of generators of electronic oscillations
Other ICT	
G01B	Measuring length, thickness; measuring angles; measuring areas; etc.
G01C	Measuring distances, levels or bearings; surveying; navigation; gyroscopic instruments; etc.
G01D	Measuring not specially adapted for a specific variable; etc.
G01F	Measuring volume, volume flow, mass flow, or liquid level; metering by volume
G01G	Weighing
G01H	Measurement of mechanical vibrations or ultrasonic, sonic or infrasonic waves
G01J	Measurement of intensity, velocity, spectral content, etc. of infra-red, visible or ultra-violet light etc.
G01K	Measuring temperature; measuring quantity of heat; thermally-sensitive elements
G01L	Measuring force, stress, torque, work, mechanical power, mechanical efficiency, or fluid pressure
G01M	Testing static or dynamic balance of machines or structures
G01N	Investigating or analysing materials by determining their chemical or physical properties
G01P	Measuring linear or angular speed, acceleration, deceleration or shock; etc.
G01R	Measuring electric variables; measuring magnetic variables
G01V	Geophysics; gravitational measurements; detecting masses or objects; tags
G01W	Meteorology
G02B6	Light guides; structural details of arrangements comprising light guides and other optical elements
G05B	Control or regulating systems in general; functional elements of such systems
G08G	Traffic control systems
G09B	Educational or demonstration appliances; models; planetaria; globes; maps; diagrams
H01B11	Communication cables or conductors
H01J	Electric discharge tubes or discharge lamps
H01L	Semiconductor devices; electric solid state devices

Source: OECD (2008)

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Table 34. Organization types and descriptors

CODE	DESCRIPTION
EDU	Universities and other educational institutions
GOV	Governmental institutions
IND	Industry
OTH	Special interest groups like unions, chambers, inter-trade organisations, etc.
ROR	Public and private research organisations

Source: EUPRO

Table 35. Country codes and group assignments

ISO CODE	COUNTRY NAME	COUNTRY GROUP**
AT	AUSTRIA	EU 27
AT22	STYRIA	Focus region (NUTS2)
AU	AUSTRALIA	High-income country
BE	BELGIUM	EU 27
BG	BULGARIA	EU 27
BY	BELARUS	ICPC* - Eastern Europe and Central Asia (EECA)
CA	CANADA	High-income country
CH	SWITZERLAND	Associated country
CL	CHILE	ICPC* - Latin America
CN	CHINA	ICPC* - Asia
CU	CUBA	ICPC* - Carribean
CY	CYPRUS	EU 27
CZ	CZECH REPUBLIC	EU 27
DE	GERMANY	EU 27
DK	DENMARK	EU 27
EE	ESTONIA	EU 27
ES	SPAIN	EU 27
FI	FINLAND	EU 27
FR	FRANCE	EU 27
FRF	GRAND EST	Focus region (NUTS1)

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GH	GHANA	ICPC* - Africa
GI	GIBRALTAR	EU 28 OCT
GR	GREECE	EU 27
HR	CROATIA	EU 27
HU	HUNGARY	EU 27
IE	IRELAND	EU 27
IL	ISRAEL	Associated country
IS	ICELAND	Associated country
IT	ITALY	EU 27
JP	JAPAN	High-income country
KE	KENYA	ICPC* - Africa
KR	KOREA, REPUBLIC OF	High-income country
LI	LIECHTENSTEIN	Associated country
LT	LITHUANIA	EU 27
LU	LUXEMBOURG	EU 27
LV	LATVIJA	EU 27
NL	NETHERLANDS	EU 27
NO	NORWAY	Associated country
PL	POLAND	EU 27
PT	PORTUGAL	EU 27
RO	ROMANIA	EU 27
RS	SERBIA	Associated country
RU	RUSSIAN FEDERATION	ICPC* - Eastern Europe and Central Asia (EECA)
SE	SWEDEN	EU 27
SE311	VÄRMLANDS LÄN	Focus region (NUTS3)
SG	SINGAPORE	High-income country
SI	SLOVENIA	EU 27
SK	SLOVAKIA	EU 27
TH	THAILAND	ICPC* - Asia
TR	TURKEY	Associated country
TW	TAIWAN, PROVINCE OF CHINA	High-income country

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UA	UKRAINE	ICPC* - Eastern Europe and Central Asia (EECA)
UK	UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND	Associated country
US	UNITED STATES OF AMERICA	High-income country
ZA	SOUTH AFRICA	ICPC* - Africa

Source: EUPRO; ISO 3166-1:2020 (https://www.iso.org/iso-3166-country-codes.html)
Notes: *) International Cooperation Partner Country. **) The UK was labelled as an Associated Country, for this reason the remaining EU member states are labelled EU 27. This re-labelling does not affect the analysis throughout the report where the UK was counted as EU 28 member state.

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Table 36. Development-oriented digitalisation in H2020: keywords and projects in the territories

TOPICKEYWORD	NUMBER OF PROJECTS	TOPICKEYWORD	NUMBER OF PROJECTS
Advanced computing	4	Mechatronics	2
Algorithms, distributed, parallel and network algorithms, algorithmic game theory	1	Micro- and nanoelectronics, optoelectronics	1
Assistive robotics	2	Microoptics	3
Automation	5	Microscopy and spectroscopy	3
Automation and control systems	7	Molecular electronics	1
Big data	1	Monitoring and control systems	4
Bus	1	Nanophotonics	3
Cloud Architectures	2	Network Security	2
Cloud computing	1	Network technologies / Internetworking	3
Cloud Computing models	2	Networks (communication networks, sensor networks, networks of robots, etc.)	6
Cloud Infrastructures	2	Networks and information security systems	2
Cloud Services	1	Numerical analysis, simulation, optimisation, modelling tools	1
Cloud trust & security	2	Open data	1
Communication engineering and systems telecommunications	9	Open Source Software	6
Communication technologies	2	Optical Communications	4
Communication technology, high-frequency technology	3	Optical design and fabrication	3
Complexity and cryptography, electronic security, privacy, biometrics	3	Optical sensors	3
Computer and information sciences	1	Optics (including laser optics and quantum optics)	4
Computer games, multi-media, augmented and virtual reality	2	Optoelectronics	4

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Computer graphics, computer vision, multi media, computer games	2	Organic and large area electronics	3
Computer hardware and architecture	3	Organic electronics	5
Computer sciences, information science and bioinformatics	2	Photonic devices	4
Computer systems, parallel/distributed systems, grid, cloud processing systems	1	Photonic integration, photonic integrated circuits	5
Computing for servers, data centres	1	Photonics	3
Control engineering	2	Photonics for safety and security	3
Cyber-physical systems	11	Photonics in computing, interconnects, data storage	1
Cybersecurity	7	Plasmonics and metamaterials	3
Data stream analysis	1	Radio Frequency / Microwave Communications	1
Electrical and electronic engineering	2	Real time data analytics	1
Electrical and electronic engineering: semiconductors, components, systems	8	Robot safety	2
Electrical engineering, Electronic engineering, Information engineering	2	Robotics	2
Electromagnetic theory and simulations	3	Robotics and automatic control	3
Electronic components	4	Scientific computing and data processing	1
Electronics, photonics	6	Scientific computing, simulation and modelling tools	1
Embedded computing	3	Semiconductors	2
Embedded systems	6	Semiconductors and Nanotechnology	1
EXP Experimental Facilities and Measurement Techniques	1	Semiconductors, components, systems	1
Fiber optics and optical communications	3	Sensor networks, embedded systems, hardware platforms	1
High performance computing	4	Simulation and design tools	3
Human robot collaboration	1	Simulation tools and technologies	6
Human robot interaction	1	Smart factories	4
III-V photonics	3	Smart manufacturing	4
Imaging, image and data processing	3	Smart objects and interaction design	1

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Industrial Automation and Robotics, mechatronics	6	Software Architectures	4
Industrial robot	2	Software Design & Development	4
Information Security	3	Software design validation and maintenance	3
Information Security Technologies	4	Software engineering, operating systems, computer languages	4
Information technologies	4	Software notation & tools	3
Instrument	3	Software quality Management	1
Internet of Things	6	System Software	3
Internet Services & Applications	4	Systems engineering, sensorics, actorics, automation	10
Interoperable secured communications (Security systems architecture)	2	Unconventional computing	1
IT Security	3	Very large data bases	1
Lasers and laser optics	3	Web and information systems, database systems, information retrieval and digital libraries, data fusion	3
Lighting, solid-state lighting, LEDs, OLEDs	3	Wireless communications, communication, high frequency, mobile technology	1
Machine learning, statistical data processing and applications using signal processing (e.g. speech, image, video)	6		

Source: EUPRO

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Table 37. Application-oriented digitalisation in H2020: keywords and projects in the territories

TOPICKEYWORD	NUMBER OF PROJECTS	TOPICKEYWORD	NUMBER OF PROJECTS
Accessibility	2	Knowledge transfer	2
Acoustics	1	Launchers	1
Adult education	1	Leadership development	1
Aeronautics and International cooperation	1	Logistics	5
Aerospace engineering	3	LSP Large scale validation Platforms	1
Agricultural biotechnology and food biotechnology	1	LSX Large scale validation Experiments	1
Agriculture	2	Manufacturing of space products	1
Agriculture related to animal husbandry, dairying, livestock raising	2	Manufacturing technologies for photonic devices	4
Agriculture related to crop production, applied plant biology	2	Market analysis	1
Agriculture, Forestry, and Fisheries	1	Market-creating innovation	6
Agronomy	2	Materials engineering	1
Analytical chemistry	1	Materials engineering (biomaterials, metals, ceramics, polymers, composites, etc.)	1
Anonymity	3	Mechanical engineering	2
Anthropology, ethnology	1	Medical biotechnology related ethics	1
Architectural design	1	Medical engineering	3
Architecture engineering	3	Medical laboratory technology (including laboratory samples analysis diagnostic technologies)	1
Architecture, smart buildings, smart cities, urban engineering	1	MET Meteorological	1
Arts, Art history	1	Metrology	1
ASD Air Safety Data analysis	1	Micro (system) engineering	1

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Atomic, molecular and chemical physics (physics of atoms and molecules including collision, interaction with radiation magnetic resonances Moessbauer effect)	1	Mining and mineral processing	1
Automotive	1	Mobility and transportation	1
Behavioural change campaigns	2	Nano-materials (production and properties)	1
Behavioural economics	1	Nanophysics: nanoelectronics, nanophotonics, nanomagnetism, nanoelectromechanics, etc.	1
Biochemistry and molecular biology	1	Nano-processes (applications on nano-scale)	4
Bioinformatics, e-Health, medical informatics	1	Nano-technology	1
Biology (theoretical, mathematical, thermal, cryobiology, biological rhythm), Evolutionary biology	1	Natural resources and environmental economics	1
Biomaterials (as related to medical implants, devices, sensors)	1	Natural resources exploration and exploitation	1
Biophotonics	3	Network infrastructures	1
Biophotonics and medical applications	3	New business opportunities	6
Biophotonics, Imaging, image and data processing	1	New industrial value chains	7
Biophysics	4	New participatory democracy models	3
Business and Management	2	Open innovation	2
Business coaching and mentoring	1	Orbital transportation and re-entry systems	1
Business development	1	Organic chemistry	1
Business environment (legal and administrative)	1	Organisation theory	1
Business management	7	Organisational management / development	2
Business model innovation	3	Organization studies: theory & strategy, industrial organization	1
Business models	3	Other biological topics	1

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Business plan	5	Other engineering and technologies	2
Business strategies	2	Other medical sciences	1
Business support services	2	Paper and wood	1
Carbon sequestration in forest (mitigation)	1	Participatory Innovation	2
Cell biology, Microbiology	1	Participatory/Participation	5
Certification, Verification, Validation, Technical Compliance, Standards	1	Particles and fields physics	1
Chemical process engineering	1	Patient safety	1
Circular economy	2	Performing arts studies (Musicology, Theater science, Dramaturgy)	1
Civil engineering	1	Personalised interventions	1
Clinical trials	1	Personalised medicine	1
Cluster dynamics	2	Pharmacovigilance	1
Clusters	2	Physical chemistry, Polymer science, Electrochemistry (dry cells, batteries, fuel cells, corrosion metals, electrolysis)	1
Collective Awareness Platforms	1	Piloting	6
Communication networks, media, information society	4	Plant sciences, botany	1
Condensed matter physics (including formerly solid state physics, superconductivity)	1	Political systems and institutions, governance	3
Construction engineering, Municipal and structural engineering	3	Precision agriculture	1
Corporate Social responsibility	1	Privacy	3
Critical infrastructure, emergency systems, security, safety engineering	2	Process innovation	3
Crowdsourcing	3	Product innovation	3
Cultural and creative economy	1	Production equipment	1
Cultural and economic geography	2	Propulsion systems engineering	1
Cultural history, cultural memory	1	Prototyping	2
Cultural studies, cultural diversity	2	Psychology (including human - machine relations)	1

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Decarbonisation	1	Psychology, special (including therapy for learning, speech, hearing, visual and other physical and mental disabilities)	1
Demand driven innovation	6	Public engagement	3
Deployment	2	Public transport	1
Design innovation	3	Pure mathematics, Applied mathematics	1
Design-Manufacturing	5	Rail infrastructure	1
Developing countries	1	Rail Operations	1
Developmental biology	1	Rail Services	1
Diagnostics	1	Rail Transport	3
Digital factories	3	Regional development	1
Digital games, gamification, applied games, serious games	2	Regulation	1
Digital identity	3	Regulatory affairs	1
Digital services	3	Related to industrial policy	1
Disruptive innovation	1	Related to SME and start-up support	1
Distributed Social Networks	1	Remote sensing	4
Due diligence	1	Renewable energy sources	1
Ecology	1	Renovation	1
Economics, Econometrics	1	Research data	1
Educational sciences	1	Resources efficiency	2
eHealth	1	Responsible Research and Innovation (RRI)	3
Emerging industries	1	Risk reduction	2
Energy Efficiency	5	Risks and vulnerabilities assessment	4
Energy efficient buildings	1	Risks assessment, modelling and impact reduction	2
ENGINEERING AND TECHNOLOGY	1	Road infrastructure	1
Entrepreneurship	2	Robotics for agriculture	2
ENV Environmental Hazard Analysis	1	Robotics for agriculture, forestry and fishing	2
Environment, resources and sustainability	1	Robotics for civil applications	2

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Environmental and geological engineering, geotechnics	1	Robotics for healthcare	2
Environmental biotechnology	1	Robotics for inspection and monitoring	2
Environmental impact assessment	1	Robotics for manufacturing	1
Environmental sciences	1	Rolling Stock Engineering	2
Environmental sciences (social aspects)	1	SAM Safety modelling	1
Equipments and sub systems	1	Scalability	1
Ethics in engineering and technologies	1	Secure Societies	3
Ethics in natural sciences	1	Security	4
Evaluation of threats and vulnerabilities	2	Security Analysis	4
Exercise and simulation, training	2	Service Engineering	1
Experimentally-driven research and innovation	3	Service innovation	1
Feasibility analysis	1	Service oriented architectures	1
Field trial	1	Signature control and signature reduction	2
Financial & Investment management	6	Smart Specialisation strategies	1
Fintech (Financial technology)	2	SME support	3
Fluids and plasma physics (including surface physics)	1	Social and economic geography	1
Folklore studies	1	Social and industrial ecology	1
Forensic technologies, others	2	Social geography, infrastructure	1
Forest adaptation to climate change	1	Social innovation	1
Forest resilience	1	Social media	1
Forestry	3	Social sciences, interdisciplinary	2
Freight and logistics	1	Sociology	1
Gender in urban planning and development	1	Spatial and regional planning	1
Geosciences, multidisciplinary	1	Spatial assessment and evaluation	1
Ground Based Facilities	1	Spatial development and architecture, land use, regional planning	1
HAZ1 Hazard Analysis: Operational safety assessment	1	Spatial planning	1

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HAZ2 Hazard Analysis: Safety requirements (rules and regulations):	1	Statistics and probability (This includes research on statistical methodologies, but excludes research on applied statistics which should be classified under the relevant field of application (e.g. Ec	1
Health care	1	Studies on Film, Radio and Television	1
Health care sciences and services (including hospital administration, health care financing)	1	Supply chain management	7
Health policy and services	2	Surgical robotics	2
Health services, health care research	3	Sustainable energy communities	1
Healthcare system	1	Sustainable innovation	4
Health-related biotechnology	4	Sustainable transport	3
Healthy ageing	1	SYC System Certification	1
Human protection	1	System of systems	3
Industrial biotechnology	1	Systems engineering	1
Industrial design	1	Systems Engineering and Design Management	2
Industrial design (product design, ergonomics, man-machine interfaces, etc.)	2	Systems Engineering and Integrated Systems Design	3
Industrial innovation policy	3	Systems of systems	2
Industrial policy	1	Systems-Services Functions	1
Industrial processes	1	Technological innovation	5
Industrial sectoral change	1	Technologies involving identifying the functioning of DNA, proteins and enzymes and how they influence the onset of disease and maintenance of well-being (gene-based diagnostics and therapeutic interv	1
Industrial waste	1	Technologies involving the manipulation of cells, tissues, organs or the whole organism (assisted reproduction)	1
Information management	2	Technologies-Components	1
Information science (social aspects)	1	Technology commercialisation	1

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Informed consent	1	Technology development	2
Innovation	3	Technology implementation	1
Innovation and diversity (e.g. gender)	1	Technology management	8
Innovation management	3	Technology transfer	3
Innovation Management Consulting	1	Traffic management and surveillance	1
Innovation methodologies	3	Transport & Mobility	2
Innovation policy	2	Transport engineering	1
Innovation strategies	2	Transport engineering, intelligent transport systems	2
Innovation support services	1	Transport planning and social aspects of transport	2
Innovation systems	3	Truck	1
Integrated platforms and systems and Human Factors	2	Trust	2
Integrated systems of systems	1	Trustworthy ICT	1
Intermodal freight transport	1	Types of innovation	1
International cooperation	3	Urban studies (Planning and development)	2
Internationalisation	1	Urban studies, regional studies	1
Internet architectures	1	Urbanization and urban planning, cities	1
Internet science, collective awareness platforms	1	Vehicle certification	1
Investment readiness	1	Vehicle engineering	2
Involvement of vulnerable populations	1	Virtual factories	3
IPR management	7	WAR Warning Systems	1
Knowledge and Technology transfer	1	Waste management	1
Knowledge infrastructure	1	Waste recycling	1
Knowledge management applied to Security issues	2	Wellbeing	1
Knowledge support networks	2	Wood harvesting	1

Source: EUPRO

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