Technological capabilities and the twin transition in Europe

Opportunities for regional collaboration and economic cohesion

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Bertelsmann Stiftung
Werderscher Markt 6
10117 Berlin
Germany

Responsible:
Thomas Schwab
thomas.schwab@bertelsmann-stiftung.de

Contributions:
Bruno Augsburg
Jake Benford
Sabine Feige
Katharina Gnath
Lucas Resende Carvalho
Malte Zabel

Graphics:
nach morgen

Editor:
David Gow

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Opportunities for regional collaboration and economic cohesion

Julia Bachtrögler-Unger (Austrian Institute of Economic Research)

Pierre-Alexandre Balland (Utrecht University & Artificial and Natural Intelligence Toulouse Institute)

Ron Boschma (Utrecht University & University of Stavanger)

Thomas Schwab (Bertelsmann Stiftung)

Abstract

Technological capabilities vary substantially across European regions. Combining these diverse sets of capabilities is crucial to develop the technologies necessary to master the green and digital transition. However, collaboration between regions is sparse today. To increase inter-regional cooperation, linkages that spur the development of green and digital technologies must be identified. In this study, we provide an overview of inter-regional collaborations already in place and map new opportunities for these between regions. A special emphasis is placed on potential collaborations between economically leading and lagging regions. Our results provide new impetus for policy designs that strengthen regional innovation capabilities and cohesion across Europe’s regions.

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As part of the “Europe's Economy” project, the Bertelsmann Stiftung investigates which economic, social and territorial imbalances are relevant for the European Union. The team analyses how the structural changes associated with the green and digital transition will affect Europe's economic base. Against this background, the project develops proposals on how to improve the EU's internal market and how the EU can make better use of its policies and resources to strengthen cohesion in Europe.

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Contents

1 Introduction

Europe's economic landscape is marked by considerable regional disparities. Over the years a deep body of knowledge has emerged with respect to drivers for regional growth and development. We know less, however, about how the structural changes required to green and digitize Europe's economy will affect regions' income and development in the future (Bertelsmann Stiftung 2022). Will these changes provide opportunities for lagging regions to catch up and thus boost overall levels of regional cohesion across Europe? Or will opportunities to master the digital and green transition fall largely upon already highly developed regions, enabling them to pull even further away from their less developed counterparts in the years ahead?

It is well-established that research and innovation play a crucial role in driving economic development in Europe's regions (Iammarino et al. 2019; European Commission 2022c), bringing with it the additional advantage of boosting Europe's global competitiveness vis-à-vis competing actors such as the US or China. The unequal distribution of capabilities for innovation and technological progress across European regions (European Commission 2021d), however, translates into correspondingly unequal regional abilities to develop the technologies called for by the twin transition. Since advances in these technologies rely on a *combination of different capabilities*, we need to, first, identify *the precise capabilities* that matter for the twin transition. Second, we need to pinpoint *which regions* can contribute to digitizing and greening Europe's economy via technological advances. The landscape of innovation-induced economic prosperity that emerges from this analysis should be of particular interest to EU policymakers focussed on the political goal of improving EU-wide regional cohesion: Should they, for instance, expect less-developed regions to lose further ground in an increasingly innovation-focussed economy, requiring compensatory measures to ensure the balanced and cohesive economic growth called for in the EU Treaties?

This implies one must assess the potential of regions to develop further and foster the broad diffusion and uptake of green and digital technologies. Many regions show high ambition to participate in the twin transition (Amoroso et al. 2021; European Commission 2022c), but only a few may have a high potential to contribute to and profit from the green and digital transition. There is indeed some evidence that regions differ in their ability to contribute to the development of green technologies (Tanner 2016; Montresor and Quatraro 2019; Van den Berge et al. 2020; Li et al. 2021; Santoalha and Boschma 2021; Balland et al., 2022). Yet there is little understanding of which European regions have the true potential to develop these technologies. Collaboration between regions also plays a crucial role. However, inter-regional collaboration is often limited, especially between countries in Europe (Balland 2022). Regions differ in their access to relevant capabilities in other regions which in turn affects their ability to develop green and digital technologies. This also implies there might be a lot of untapped potential in inter-regional linkages in Europe.

Against this background, our objective is to map the potential of European regions to develop green and digital technologies. This mapping exercise serves two purposes. First, to identify the regions with the highest potential to develop specific twin transition technologies (such as batteries or Artificial Intelligence). This mapping can be used to target the technologies that best fit a specific regional ecosystem and accelerate EU regional innovation and the twin transition. Second, this mapping allows for strategically harnessing the untapped potential in lagging regions and promoting greater cohesion throughout Europe. Ideally, both these goals can be achieved in a mutually supportive manner.

The questions addressed in this study are thus as follows:

1. What does the landscape of green and digital technologies in Europe look like today? Which regions in Europe are spearheading the development of twin transition technologies?

2. What does the future geography of twin transition technologies in Europe look like? Which regions in Europe have the potential to develop twin transition technologies in the near future?

3. To what extent are European regions collaborating in the development of twin transition technologies, and how much untapped potential for more and better collaboration is there that could foster cohesion?

To assess European regions' technological potentials for the twin transition, we apply a framework developed by Balland et al. (2019) and Balland and Boschma (2021b) that builds on three key concepts: *relatedness*, *complexity* and *inter-regional linkages*.

Relatedness refers to the costs that a region has to incur when moving into a new technology (Breschi et al. 2003; Boschma 2017; Hidalgo et al. 2018). These costs will be lower the greater the overlap between the capabilities required to develop the new technology on the one hand, and the supply of existing capabilities in the region on the other. The more related current and new technologies are, the less risky and less costly it is for a region to develop the new technologies. Research shows that regions do indeed tend to diversify into new activities closely related to their existing capabilities, no matter whether it concerns diversification in new industries (Neffke et al. 2011), jobs (Muneepeerakul et al. 2013) or technologies (Rigby 2015). The relatedness concept is used as a key principle in Smart Specialisation policy in the EU to select new domains of specialisation in regions that complement and leverage their local capabilities (Foray et al. 2009, 2012; McCann and Ortega-Argilés 2015; Iacobucci and Guzzini 2016). In this study, we investigate whether the technological knowledge base of high- and low-income EU regions is related to green and digital technologies. The intuition behind it is that regions with relevant (related) pre-existing capabilities are better placed to profit from the twin transition.

Complexity refers to the potential economic benefits of regional technological diversification. The benefits will be higher the greater the complexity of economic activities (Hidalgo and Hausmann 2009). As complex activities combine many capabilities, it is harder for other regions to copy and develop them. This implies that complex activities may provide a more sustainable source of regional competitiveness (Maskell and Malmberg 1999; Fleming and Sorenson 2001). By contrast, low-complex activities can be undertaken by many regions, suggesting their lower economic value (Balland and Rigby 2017; Rigby et al. 2022). So, when mapping diversification opportunities, it is crucial to not only consider local technological capabilities but also the complexity of the activities concerned. Studies show that regions differ widely in their ability to move into complex activities (Pinheiro et al. 2022). Some have a strong capacity to develop high-complex activities because their local capabilities fit the bill. Others have high potential in low-complex activities alone, which has major economic implications. When mapping the technological opportunities of high- and low-income regions to master the twin transition, we will also assess whether the digital and green technologies in question are low- or high-complex technologies.

Focussing solely on local capabilities is, however, not the whole story. Other regions may also affect the development of new technologies in a given region. Regions that lack relevant capabilities to develop twin transition technologies may connect to others to exploit complementarities across countries and regions. Thus, *inter-regional linkages* are considered crucial for innovation because they provide access to new knowledge and ideas, and they would help regions to overcome lock-ins (Grabher 1993). This tendency of regions to get locked-in is often attributed to local agents searching for new knowledge close by, within their own cognitive domains, their own networks, and in their own places of work (Nooteboom 2000; Boschma 2005). However, inter-regional linkages are not a sufficient condition: not all non-local knowledge is relevant for regions, and not all linkages to other regions matter for the capacity of a region to innovate (Boschma and Iammarino 2009; Boschma et al. 2014; Miguelez and Moreno 2015, 2018; Barzotto et al. 2019). Balland and Boschma (2021b) showed that linkages giving access to capabilities in other regions that complement existing capabilities of a region are important for that region's ability to diversify in new technologies. So, it is not simply about being exposed to the outside world. Instead, the presence of complementary inter-regional linkages increases the probability that regions successfully diversify into new activities. This implies that advancing the twin transition in Europe means exploiting and increasing inter-regional cooperation – including across member states.

This study examines whether high- and low-income regions are connected to the right set of regions in Europe: regions that provide them with access to complementary capabilities that are needed to develop the twin transition technologies. In an ideal European innovation network, complementarities based on regional capabilities are fully exploited – both within a country and across national borders. We compare the ideal network for green and digital technologies with current patenting collaborations in these technological fields. In doing so, the study generates new insights into untapped potential for further inter-regional technological cooperation.

We find, that, first, Europe’s landscape of green and digital technologies today is marked by high levels of concentration of key twin transition technologies in more developed regions: more than 80% of twin transition technologies are found here. An exception that proves the rule is some “hidden twin transition champions”, i.e., less developed and transition regions that hold valuable capabilities particularly in technologies key to the twin transition.

Second, further (complex) technological development across European regions is a distinct possibility. The highest potential to develop new complex technologies, i.e., technologies with high economic returns, lies once more in more developed regions. Some less developed and transition regions could also develop twin transition technologies. Yet their potential here is in green rather than digital technologies, and more often in low-complex rather than high-complex technologies.

Third, the study identifies two striking patterns in the current state of inter-regional collaboration on twin transition technologies: On the one hand, collaboration takes place mainly within national borders. On the other hand, all types of regions in Europe – whether less developed, in transition or more developed – collaborate mostly with more developed regions. Conversely, there remains substantial unrealised potential in the EU to combine complementary regional technological capabilities, particularly by collaborating across national borders. Crucially for cohesion effects, this untapped potential exists for all types of regions, including collaborations between less developed and transition regions.

2 Key technologies for the digital and green transition in Europe

The first step is to select technologies that are associated with the twin transition. We screened for key technologies mentioned in official documents of the European Union's green and digital agendas. Further, we identified the relevant economic sectors expected to help the EU reach its digital and green goals. Based on further literature research, we derived the relevant technologies in these sectors (Bertelsmann Stiftung 2020; European Commission 2020a, 2020b; 2021a, 2021b, 2021c, 2022e, 2022f, 2022g; European Environment Agency 2020; International Energy Agency 2020; Codagnone et al. 2021; Electronics 2022). In addition, we explored studies that identified key digital and green technologies using patent data (Haščič and Migotto 2015; Ménière et al. 2017; Ciffolilli and Muscio 2018; Fushimi et al. 2018; Montresor and Quatraro 2019; Van den Berge et al. 2020; Balland and Boschma 2021a; Santoalha and Boschma 2021; Cicerone et al. 2022).

Based on this selection, we identified 18 digital and 24 green technologies shown in Table 1. This list represents the technologies usually associated with the twin transition in the literature and public debate. It is important to note that not every technology contributes in a similar way to the twin transition. Equally, not every technology is undisputed concerning its contribution to the twin transition, as the controversy surrounding nuclear energy demonstrates (see, e.g., Abousahl et al. 2021; Lynas 2021; Conea 2022). Furthermore, the mix of twin transition technologies may eventually change with new technologies becoming relevant while others vanish in importance.

Technological capabilities in these 42 twin transition technologies can be measured by patent output as a standardized measure, which allows for cross-country comparisons at regional level. Patent data is collected by public administrations and reflects key elements of technological activity in European regions.[1] We use patent applications filed at the World Intellectual Property Organization from the OECD REGPAT – 2022 edition, covering the time span 2017 – 2021. We identified patents in the twin transition technologies outlined in Table 1. Using classifications from OECD and WIPO as well as text mining, we were able to select from about 250,000 subclasses (as defined by the Cooperative Patent Classification CPC) those relevant for the twin transition. The selection of twin transition technologies corresponds to a sample of 211,790 patents registered in 288 European NUTS-2 regions (234 located in EU-27 member states and 54 in Switzerland, Iceland, Liechtenstein, Norway, and the United Kingdom). Of those, around 36% (75,673) correspond to at least one green technology class, while the majority of 64% (136,117) to at least one digital technology class.

[1] Note that innovation activity does not fully translate into patent output. Innovation activity measured by R&D expenditures is highly correlated with patent output. However, there exist substantial differences in the size of this correlation, depending on, e.g., sectors of R&D (business, higher education, public) and countries (Pegkas et al. 2019).

Table 1: Relevant technologies for the twin transition

Digital technologies	Green technologies
Artificial intelligence	Wind energy
Virtual reality and augmented reality	Solar (thermal) energy
High performance computing/quantum computers	Geothermal energy
Cloud and edge computing	Marine energy
Internet of things	Hydropower
Cybersecurity (privacy-enhancing technologies)	Nuclear energy
Cryptography, distributed ledger technology	Biofuels
Robotics	Fuels from waste
Smart grids	Hydrogen fuels
Autonomous mobility	Battery technology
Additive manufacturing (3D printing)	Recycling
Broadband	Water treatment
5G	Carbon (GHG) capturing technology
Semiconductors	Electric vehicles
Advanced materials/nanomaterials	HVAC systems
Big data	Heating pumps
Photonics	Sustainable packaging
Drones	Biocides
	Bio fertilizers
	Smart farming
	Waste management
	Energy conservation technologies
	Green construction/buildings
	Advanced sustainable materials (composite)

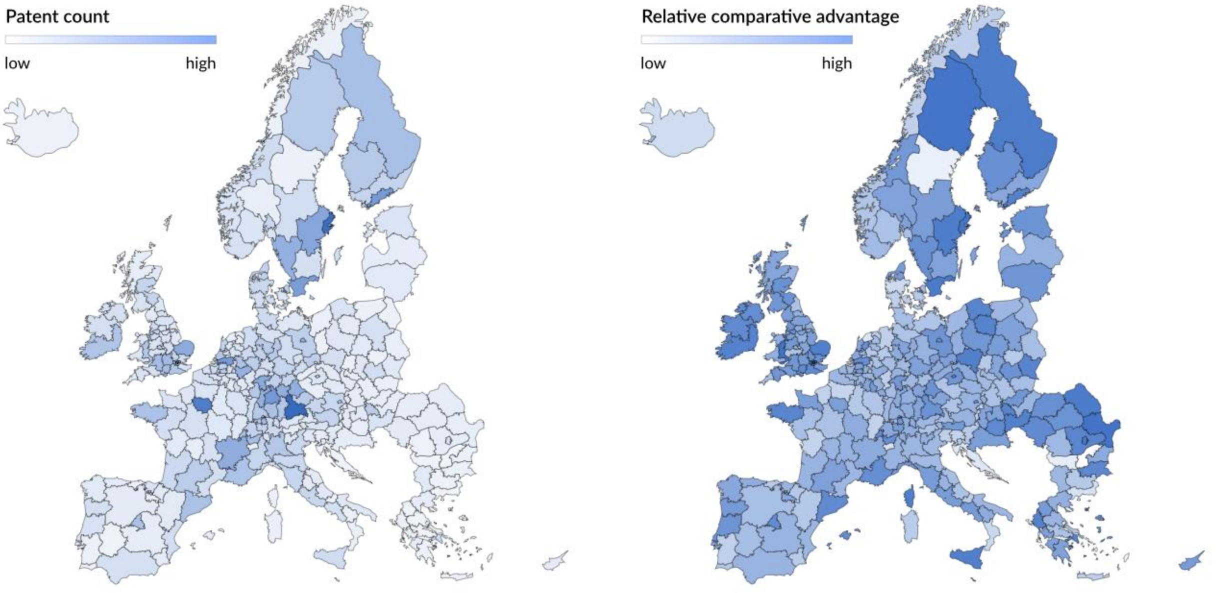
Source: Authors' own elaboration.

3 Twin transition technologies and inter-regional cooperation in Europe today

3.1 Distribution of technologies across European regions

Measured in terms of patent output, what does the geography of twin transition technologies in Europe look like today? To answer this question, we use the precise geolocation of the invention (home address of inventors) that is reported in each of the patent documents to assign the place of knowledge production to one or more European NUTS-2 regions. This allows us to map the current regional distribution of knowledge production in twin transition technologies.

Figure 1: Patenting activity and specialisation of European regions in digital technologies



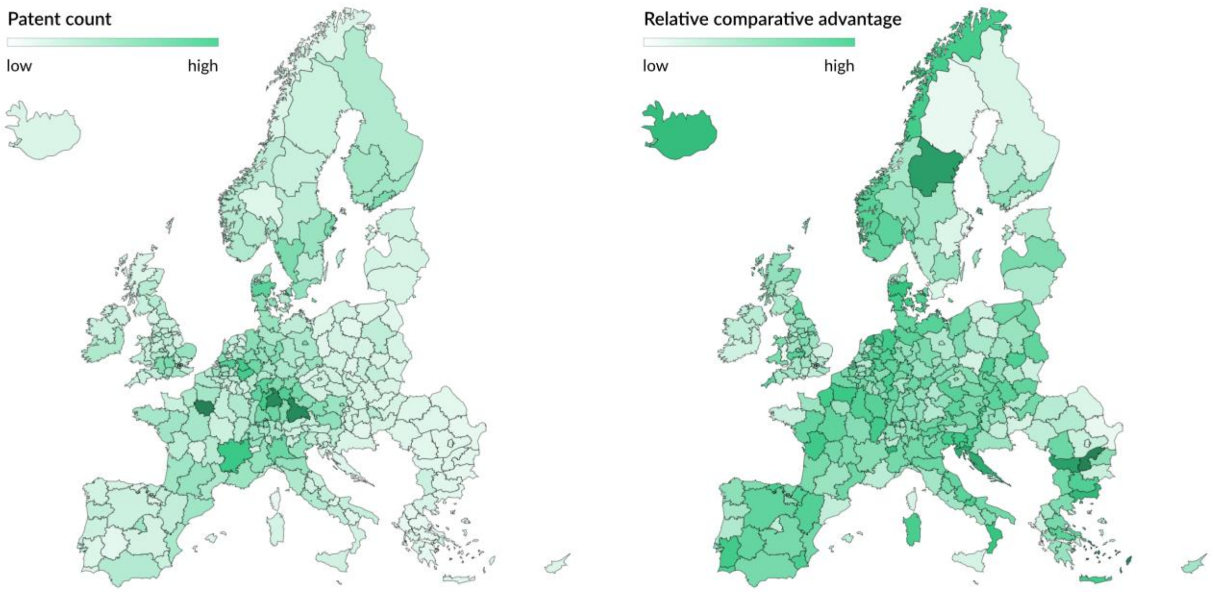
Notes: The left panel shows the absolute number of patents in digital technologies in European NUTS-2 regions. The right panel shows the RCA (share of patents in digital technologies in a region in relation to the average share among all regions). The higher the RCA value, the higher the specialisation of a region in digital technologies. Source: OECD REGPAT, own calculation.

Figures 1 and 2 highlight today's landscape of twin transition technologies in Europe. The left panels plot the geographical distribution of the absolute number of patents in digital and green technologies, while the right panels show the specialisation in digital and green technologies that a region has compared to all other European regions. This is measured by a region's relative comparative advantage (RCA).[2] An RCA higher than unity denotes that a region has a higher share of digital or green patents among all its patents than the European regional average, indicating that it is specialised in digital or green technologies. However, specialisation in a technology (high RCA) does not necessarily imply a high level of patents. For example, the region with the highest RCA among twin

[2] The relative comparative advantage measures the share of patents in a specific technology (or in a group of technologies such as digital or green technologies) among all patents in a region relative to the European average share of patents in this specific technology (or group of technologies): $RCA_{r,i} = 1 \; if \; \frac{patents_{r,i}}{patents_r} / \frac{patents_i}{patents} > 1$.

transition technologies (18.8) in electric vehicles (EVs) is the Italian region of Valle d'Aosta, but it produced just 29 patents in this technology. This is very different from the German region Oberbayern that has the highest number of patents in EVs (1,161) but exhibits an RCA of only 1.8. Hence, to assess technological capabilities of regions in digital and green technologies, one should look at both patent numbers and RCA.

Figure 2: Patenting activity and specialisation of European regions in green technologies



Notes: The left panel shows the absolute number of patents in green technologies in European NUTS-2 regions. The right panel shows the RCA (share of green patents in a region in relation to the average share among all regions). The higher the RCA value, the higher the specialisation of a region in green technologies. Source: OECD REGPAT, own calculation.

When looking at the maps based on absolute numbers of patents (left panels of Figure 1 and 2), we find a high number of patents in twin transition technologies in Sweden (especially in Stockholm and South Sweden) and Finland (in particular, Helsinki), in the Netherlands (especially Noord-Brabant), in some core regions of Germany (in particular Oberbayern and Stuttgart), France (Île-de-France and Rhône-Alpes are outstanding), Northern Italy (Lombardia) and Spain (the capital region of Madrid).

The regional differences in specialisations based on RCA are less pronounced (right panels of Figure 1 and 2). Part of the explanation is that while some less developed regions in Poland, Romania and Bulgaria are highly specialised in digital or green technologies (with a high RCA), their patenting activity in number terms is relatively low. Still, a large variation across regions can be observed, especially for digital technologies. Regions in Sweden, Finland and Romania stand out, but Sicily, say, also demonstrates high RCA scores. For green technologies, some regions show high specialisations, as in Denmark, Bulgaria, the Netherlands, Italy and Romania.

Figure 3 displays the twin transition profiles of European regions in terms of their relative focus on patenting in digital versus green technologies. Regions in blue are those with a digital profile. This means their share of digital patents of total patenting in digital and green technologies is above 64%, the average proportion in digital technologies across all European regions. Regions with a green profile have a share of green patents of the total sum of twin transition technologies larger than 36%, the average of green technologies across all European regions. The darker the blue (green) colour, the larger the share of digital (green) patents in a region. Light colourings denote a rather balanced share between digital and green patents. In general, we see that most European regions have a clear focus either on green or digital technologies. Most regions in Romania, Hungary, Finland, Ireland and the UK, as well as a majority in Sweden and Poland, have a considerably higher proportion of patents in digital technologies. By contrast, there is substantial variation in technological profile in regions within the same country in Portugal, Italy, France, Germany and Norway. Technological capabilities within capital regions tend to be more focused on the digital transition (with Hovedstaden in Denmark being one of the few exceptions), even if the surrounding regions are not (such as in Madrid or Vienna). A relatively strong green profile can be found in almost all regions in Slovenia, Denmark, Slovakia and Bulgaria. The regions with the strongest green profiles are located in Southern Romania, Western Croatia and Northern Scandinavia. Regions in Spain, France and Denmark, as well as in Northern Germany, also predominantly exhibit green profiles.

So far, we have discovered considerable differences in patenting activity in digital and green technologies across European regions. But how is the distribution of digital and green technologies related to economic prosperity? To shed light on this, we analyse the distribution of twin transition technologies among the three groups of regions usually distinguished in the framework of EU cohesion policy: less developed regions (73 NUTS-2 regions in the EU-27), transition regions (68 regions), and more developed regions (93 regions).[3]

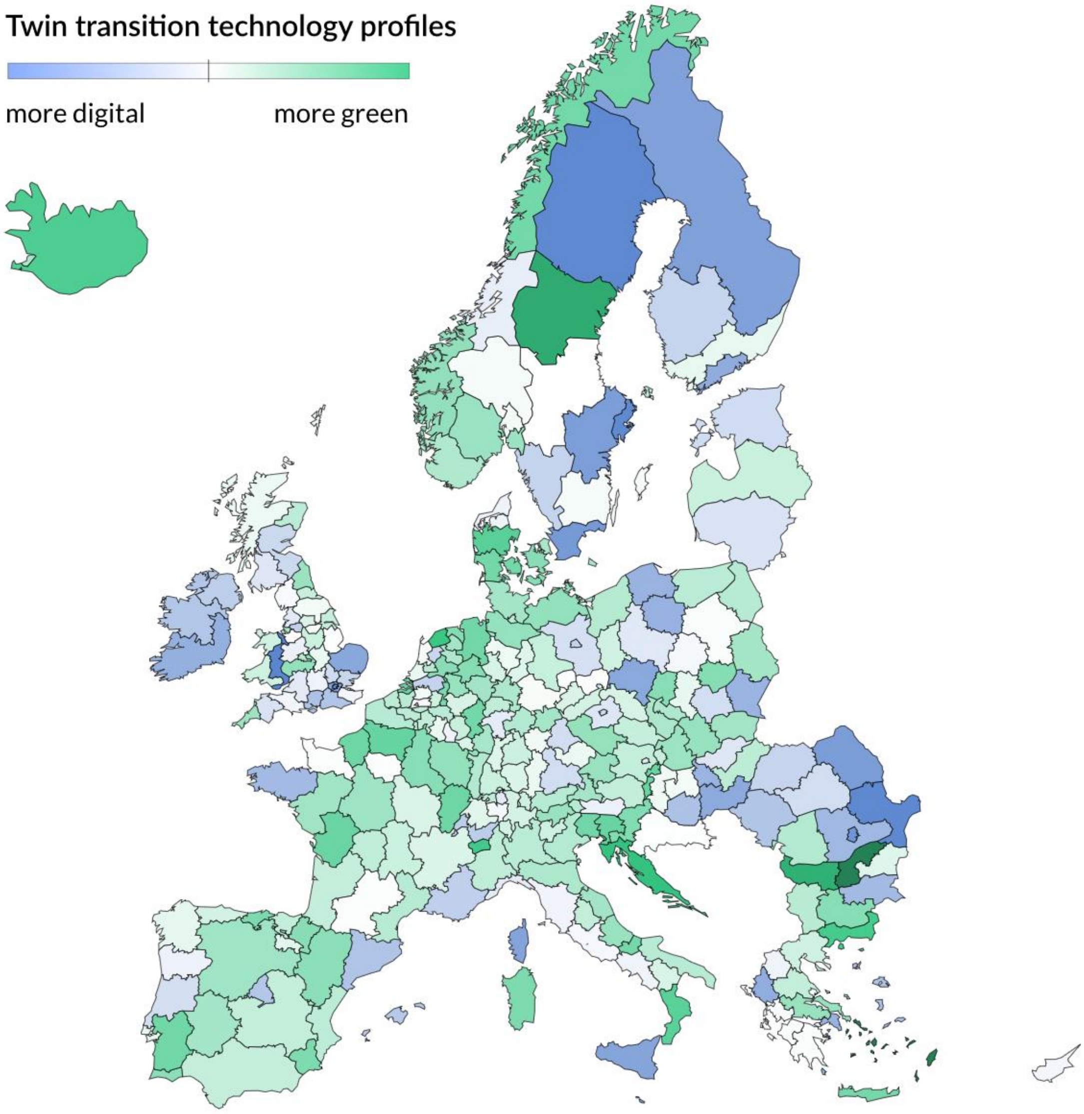
With a total of 146,401 patents, the group of more developed regions accounts for the vast majority of patents in twin transition technologies. This means that each more developed region created 1,574 patents on average during the period under investigation.[4] Transition regions account for 23,675 patents in total, or on average 348 per region. For less developed regions, 4,957 twin transition patents, or on average 68 per region, are recorded. The distribution of digital and green profiles does not vary substantially across the three groups (the share of digital patents ranges from 60 to 64% of all twin transition patents).

The variation at the level of single technologies is substantially larger (see Appendix A.2). For example, more developed regions focus more on 5G, semiconductors, additive manufacturing and photonics among digital technologies and on electric vehicles and battery technology among green technologies. In contrast, less developed regions have higher shares in their digital patent output in cybersecurity, cloud and edge computing as well as AI and for green patent output in recycling technologies, biocides and biofuels. Hence, despite more developed regions generate most patents, some less developed regions contribute significantly to the development of twin transition technologies.

[3] See Appendix A.1 for details on the classification of NUTS-2 regions and the NUTS version used.

[4] Within the group of more developed regions, patent output is also highly concentrated. Most green and digital patents were recorded in Oberbayern (12,911), Île-de-France (10,585) and Stockholm (9,510), which in sum accounted for more than one fifth of total twin transition patents in the more developed regions.

Figure 3: Focus on digital or green technologies: Different technological profiles in European regions



Notes: This map shows the twin transition technology profiles of European NUTS-2 regions. Regions are coloured in blue if the share of digital patents among their patent record in twin transition technologies is higher than 64% (i.e., the average of all European regions). They are coloured in green if their share of green patents among twin transition patents is higher than 36% (i.e., the average of all European regions). Source: OECD REGPAT, own calculation.

European regions with strong profiles in digital or green technologies

Table 2 lists the 10 European regions with the highest share of green and digital patents among all twin transition patents. Four regions in Sweden, three in Romania and two in the UK dominate the Top 10 with the strongest digital profiles in Europe. East Wales is the region with the strongest digital profile (93% of patenting in digital technologies out of all twin transition technologies), followed by Sud-Est in Romania, Övre Norrland in Sweden, Stockholm (all with around 92%) and Inner London (91%).

The 10 regions in Europe with the strongest green profiles are more spread out. The Swedish region of Mellersta Norrland leads with 90% of all patents corresponding to green transition technologies out of the sum of all twin transition technologies, followed by Jadranska Hrvatska in Croatia (85%), Friesland in the Netherlands (83%), Valle d'Aosta (80%), Italy, as well as Landsbyggð in Iceland (78%).

Table 2: Top 10 European regions with the strongest profiles in digital and green technologies

	Digital technologies			Green technologies		
#	Region	Share of patents	Patents	Region	Share of patents	Patents
1	UKL2 East Wales	92.8%	1072	SE32 Mellersta Norrland	90.1%	91
2	RO22 Sud-Est	92.3%	26	HR03 Jadranska Hrvatska	84.6%	13
3	SE33 Övre Norrland	92.2%	897	NL12 Friesland	82.5%	126
4	SE11 Stockholm	91.9%	9510	ITC2 Valle d'Aosta	80.5%	41
5	UKI1 Inner London	90.6%	4257	IS02 Landsbyggð	77.8%	27
6	RO32 București-Ilfov	88.8%	152	DK04 Midtjylland	75.4%	1644
7	SE22 Sydsverige	88.0%	4082	ITF6 Calabria	75.0%	48
8	RO21 Nord-Est	87.2%	39	FR22 Picardie	72.1%	420
9	SE12 Östra Mellansverige	87.0%	3343	SI04 Vzhodna Slovenija	71.9%	64
10	FI1D Pohjois- ja Itä-Suomi	86.5%	1566	AT11 Burgenland	71.6%	74

Notes: The column *Share of patents* denotes the share of digital or green patents of the total sum of twin transition patents in a NUTS-2 region. The column *Patents* reports the total number of green or digital patents in the respective NUTS-2 region. A minimum of more than ten patents was imposed for the selection of regions. Source: REGPAT, own calculation.

Hidden twin transition technology champions in less developed EU regions

Although patent output in twin transition technologies is concentrated in more developed regions, we find several "hidden champions" in the group of less developed regions. In Table 3, we list seven less developed regions chosen because of their above-average patenting activity in specific technologies. Of these, Andalucía (Spain) stands out with a specialisation of patent output relative to the EU average in two digital and six green technologies. Also, the regions of Sicily (Italy), Małopolskie (Poland) and Norte (Portugal) have relatively strong patent outputs in two digital technologies each.

Table 3: Examples of hidden champions in twin transition technologies among less developed EU regions

NUTS-2 region	Technology	Patents	EU avg. patents	RCA
ES61 Andalucía	Advanced materials/nanomaterials	20	11.0	2.80
	Artificial intelligence	22	21.9	1.42
	Biocides	25	14.3	2.68
	Biofuels	23	10.8	3.52
	Fuels from waste	12	3.9	5.03
	Recycling technologies	17	12.3	2.32
	Solar energy	30	20.5	2.38
	Waste management	17	10.9	2.61
HU33 Dél-Alföld	Robotics (autonomous)	18	7.2	16.04
ITF3 Campania	Cybersecurity	39	31.4	2.46
ITF4 Puglia	Advanced materials/nanomaterials	15	11.0	4.63
ITG1 Sicilia	Cryptography and distributed ledger technology	46	15.3	8.24
	Cybersecurity	53	31.4	5.11
PL21 Małopolskie	Advanced materials/nanomaterials	15	11.0	3.10
	Cloud and edge computing	26	16.5	3.60
PT11 Norte	Advanced materials/nanomaterials	12	11.0	2.29
	Autonomous mobility	36	23.5	3.44

Notes: The column *Patents* reports the number of patents in the NUTS-2 region for a given technology. The column *EU avg. patents* refers to the average patent count in all EU NUTS-2 regions for this technology. The column *RCA* lists the relative comparative advantage a NUTS-2 region exhibits in this technology. NUTS-2 Regions are selected based on three criteria: i) number of patents in a technology greater than 10, ii) number of patents higher than the average patent count in this technology across all EU regions, and iii) a specialisation in this technology (RCA > 1). Source: OECD REGPAT, own elaboration.

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3.2 Inter-regional cooperation in technologies in Europe

So far, we have looked at patenting activity in twin transition technologies *within* European regions. However, innovation and technological development also occurs *across* regional borders. The role of inter-regional cooperation for innovation has gained increasing attention (Balland and Boschma 2021b). An objective of EU cohesion policy is to close the research and innovation divide between European regions. One way to achieve that is to strengthen inter-regional knowledge flows and promote cooperation between leading and lagging regions in innovation, such as the implementation of regional innovation partnerships in the 2021-2027 programming period (Pontikakis et al. 2022).

To analyse existing inter-regional linkages in the field of green and digital technologies, we use the information on home addresses of inventors in each patent document. We count how often inventors living in one NUTS-2 region cooperated in the development of digital and green technologies with inventors residing in other regions. Figure 4 shows the strongest inter-regional linkages in digital technologies patenting activities between EU regions, while Figure 5 maps the strongest inter-regional collaboration in green technologies. Both figures show strikingly that EU regions strongly prefer to collaborate with regions *within* their national borders. This national bias can be observed not only in larger member states such as Italy, Germany or France, but also for smaller ones, as the cases of Belgium, the Netherlands and Denmark demonstrate.

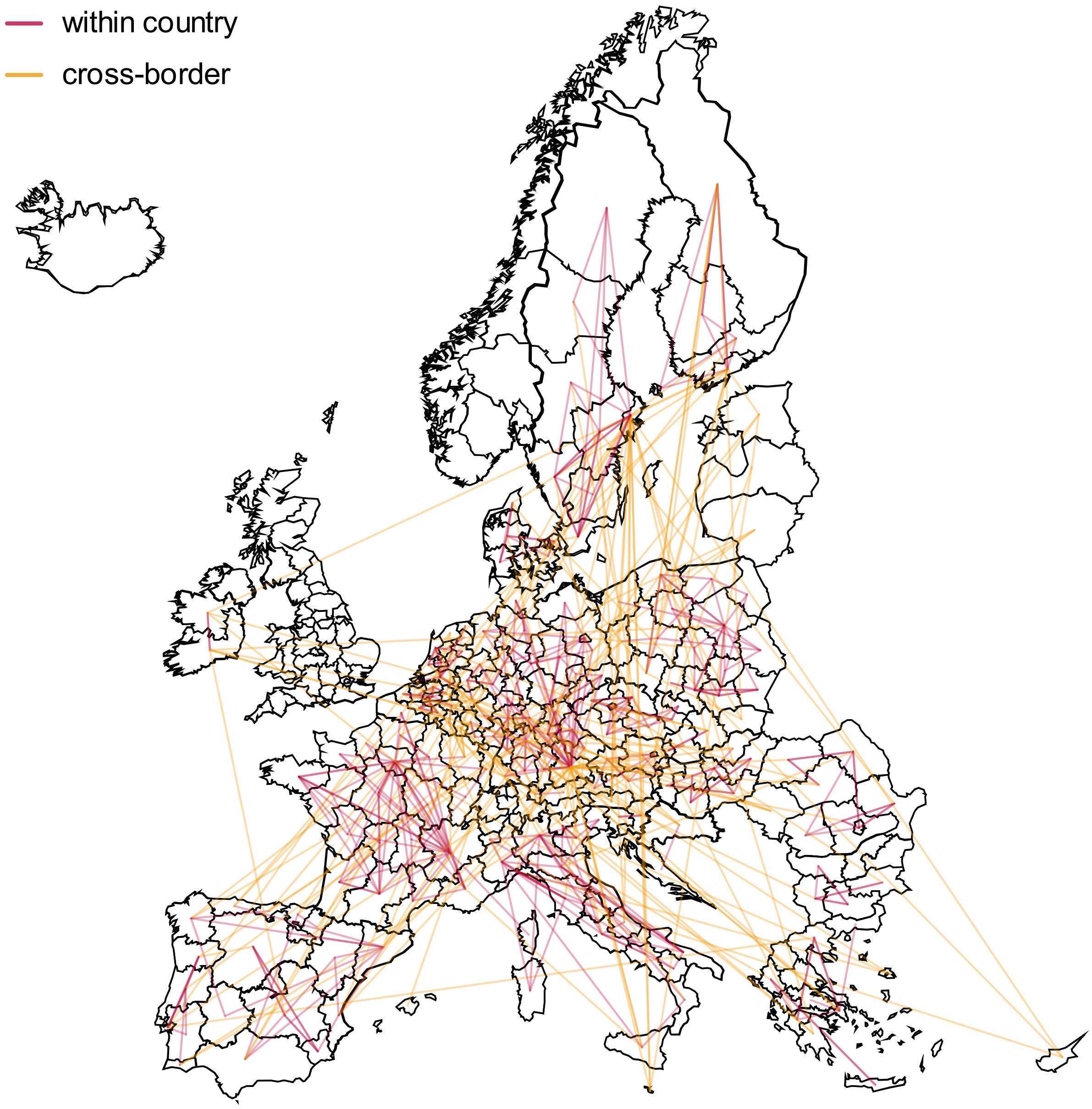
Table 4 shows the number of inter-regional collaborations in twin transition patents between more developed regions, transition regions and less developed regions. We counted a total of 111,992 inter-regional linkages in patent documents concerning the twin transition technologies under investigation. The number of inter-regional linkages for more developed regions amounts to 91,349, or more than 80% of all linkages. 16,621 linkages are recorded for transition regions, and 4,022 linkages for less developed regions. Table 4 indicates that each group of regions predominantly cooperates with more developed regions. Only 3% of the inter-regional linkages of the more developed regions and transition regions concern less developed regions. This reflects the overall importance of more developed regions as the main hubs of patenting activity.

Table 4: Inter-regional technology linkages between groups of EU regions

	Inter-regional linkages	**Share of inter-regional linkages with**		
		more developed regions	transition regions	less developed regions
More developed regions	91,349	84.2%	13.2%	2.6%
Transition regions	16,621	72.4%	24.6%	3.0%
Less developed regions	4,022	58.4%	12.3%	29.3%

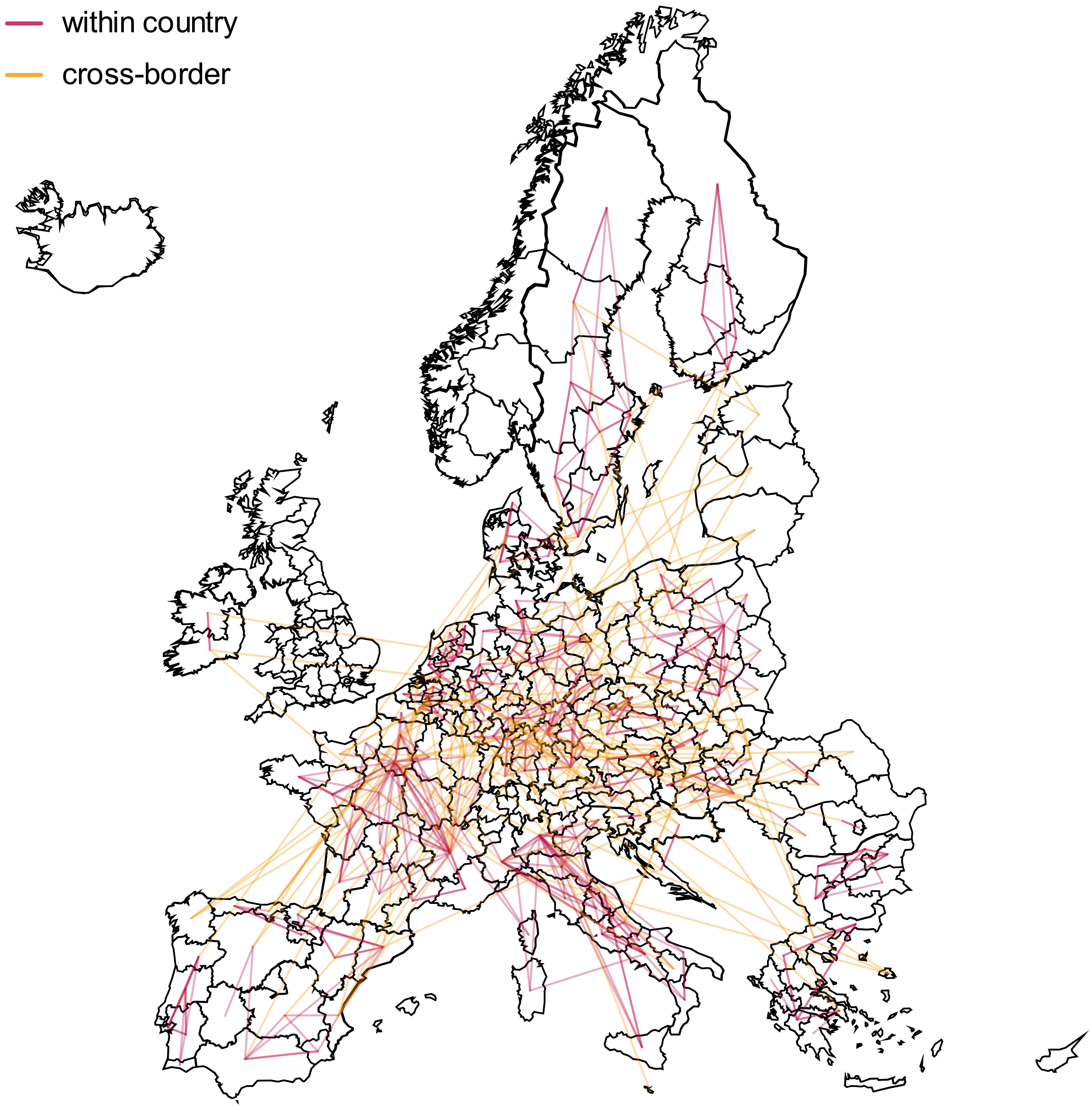
Notes: The column *Inter-regional linkages* indicates the total number of linkages between EU NUTS-2 regions. For the classification of regions into the groups of more developed/transition/less developed regions see Appendix A.1. Source: OECD REGPAT, own elaboration.

Figure 4: Strong national bias in inter-regional collaboration in digital technologies across the EU



Notes: This map shows the three strongest inter-regional linkages in digital technologies for each EU NUTS-2 region. Strength is measured by the number of cross-border collaborations in digital technology patenting. Linkages within the same EU country are shown in red, cross-border linkages are shown in yellow. Source: OECD REGPAT, own elaboration.

Figure 5: Strong national bias for inter-regional collaborations in green technologies across the EU



Notes: This map shows the three strongest inter-regional linkages in green technologies for each EU NUTS-2 region. Strength is measured by the number of cross-border collaborations in green technology patenting. Linkages within the same EU country are shown in red, cross-border linkages are shown in yellow. Source: OECD REGPAT, own elaboration.

Table 5 shows the number and shares of inter-regional linkages within the same country and across national borders for the three groups of EU regions. Most linkages are found between regions within the same country. Across all EU regions, only 26% of existing inter-regional connections in patents of digital and green technologies are cross-border linkages. Of note: the share of cross-border linkages is highest for less developed regions (37%). At the same time, the share of cross-border linkages is considerably higher for digital technologies (ranging from 29% for more developed to 38% for less developed regions) than for green technologies (ranging from 19% for more developed to 35% for less developed regions). Hence, while more developed EU regions exhibit by far the highest number of inter-regional linkages, they also cooperate significantly less with cross-border regions.

Table 5: Inter-regional linkages in digital and green technologies – within and across EU countries

	Digital technologies			**Green technologies**		
	Inter-regional linkages	Share of inter-regional linkages		Inter-regional linkages	Share of inter-regional linkages	
		within country	cross-border		within country	cross-border
More developed regions	56,787	71%	29%	34,562	81%	19%
Transition regions	9,414	70%	30%	7,207	78%	22%
Less developed regions	2,579	62%	38%	1,443	65%	35%

Notes: The columns *Inter-regional linkages* refer to the number of linkages in digital and green technologies between EU NUTS-2 regions. For the classification of regions into the groups of more developed/transition/less developed regions see Appendix A.1. Source: OECD REGPAT, own elaboration.

Selected EU regions collaborating most with other regions in twin transition technologies

European regions differ in their level of inter-regional collaboration. In the following, we list the Top 5 EU regions that have the highest number of inter-regional linkages in digital and green technologies for each group of regions. For digital technologies (Table 6), the Top 5 more developed regions are found in Sweden, Germany and Finland. For the group of transition regions, the most connected regions are in Finland, Germany and France. Among the group of less developed regions, regions in Hungary, Italy and Poland lead the field in inter-regional linkages.

Table 6: Top 5 regions with most inter-regional linkages in digital technology patents

	More developed regions		Transition regions		Less developed regions	
#	**Region**	**Linkages**	**Region**	**Linkages**	**Region**	**Linkages**
1	SE11 Stockholm	6,089	FI1D Pohjois-ja Itä-Suomi	957	HU33 Dél-Alföld	254
2	DE21 Oberbayern	3,893	DE40 Brandenburg	670	ITG1 Sicilia	253
3	SE12 Östra Mellansverige	2,969	FI1C Etelä-Suomi	513	HU22 Nyugat-Dunántúl	136
4	FI1B Helsinki-Uusimaa	2,874	FR82 Provence-Alpes-Côte d'Azur	452	PL21 Małopolskie	136
5	SE22 Sydsverige	2,647	DEG0 Thüringen	426	ITF3 Campania	122

Notes: The column *Linkages* reports the total number of inter-regional linkages between the respective NUTS-2 region and others in the EU. Source: OECD REGPAT, own elaboration.

For green technologies (Table 7), German regions dominate the Top 5 ranking in terms of inter-regional collaboration, both among the more developed regions and among transition regions. For less developed regions, the pattern of inter-regional connectedness in the field of green technologies is more diverse.

Table 7: Top 5 regions with the most inter-regional linkages in green technology patents

	More developed regions		Transition regions		Less developed regions	
#	**Region**	**Linkages**	**Region**	**Linkages**	**Region**	**Linkages**
1	DE11 Stuttgart	1,853	FR82 Provence-Alpes-Côte d'Azur	361	PL21 Małopolskie	96
2	DEA1 Düsseldorf	1,702	DE93 Lüneburg	292	SI03 Vzhodna Slovenija	81
3	DE12 Karlsruhe	1,638	DEE0 Sachsen-Anhalt	288	ITF4 Puglia	71
4	DE21 Oberbayern	1,516	DED2 Dresden	277	ES61 Andalucía	68
5	DEA2 Köln	1,443	DE40 Brandenburg	273	PT11 Norte	68

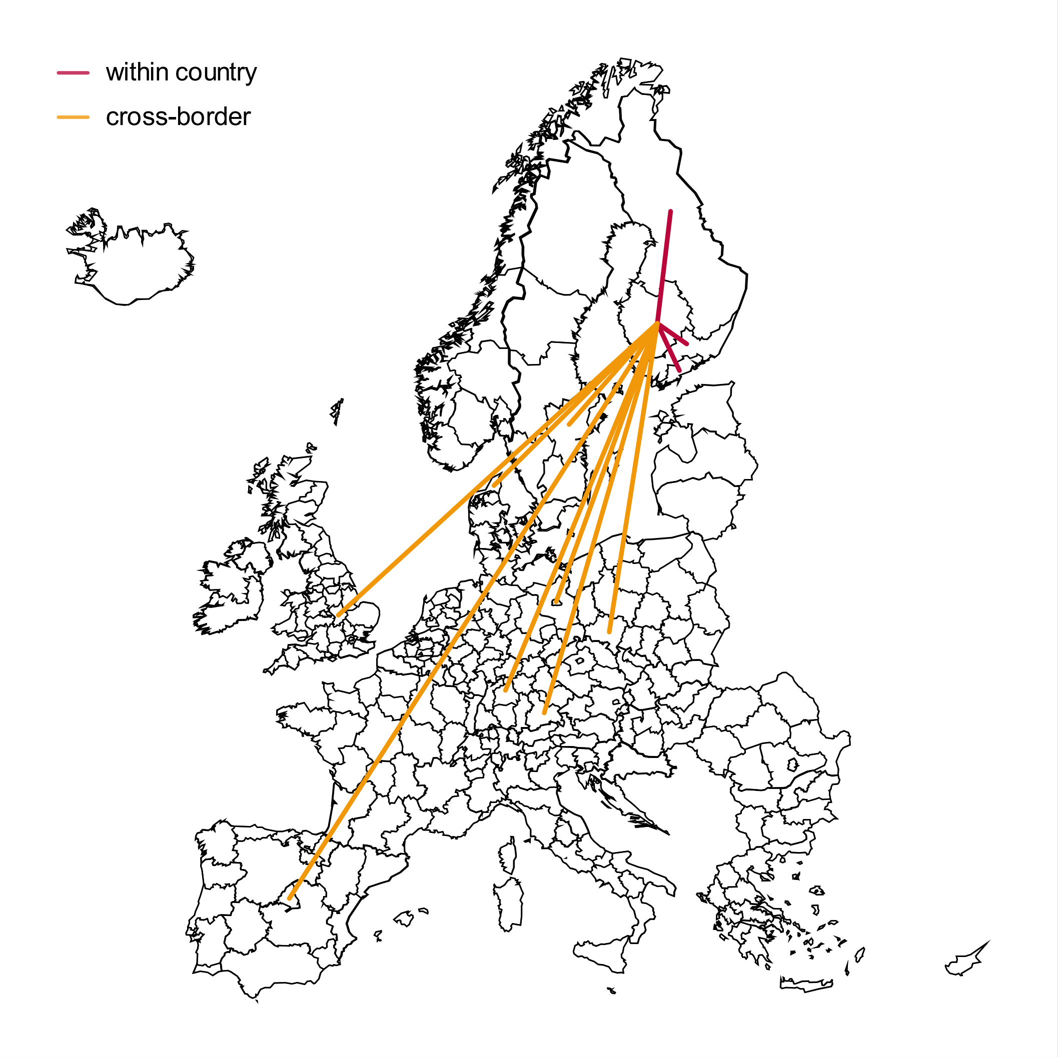
Notes: The column Linkages reports the total number of inter-regional linkages between the respective NUTS-2 region and others in the EU. Source: OECD REGPAT, own elaboration.

Three examples of European inter-regional collaborations in twin transition technologies

In the following, we provide three examples for inter-regional collaborations in specific technologies to demonstrate the heterogeneity of patenting collaboration across EU regions.

We start with the more developed region of Länsi Suomi in Finland for 5G technology. Figure 6 shows its linkages with other regions recorded in patents. Länsi Suomi cooperates with three other Finnish regions (Pohjois- ja Itä-Suomi, Helsinki-Uusima and Etelä Suomi). Further collaborations exist with regions in Poland, Sweden, Denmark, Germany, Spain and the UK.

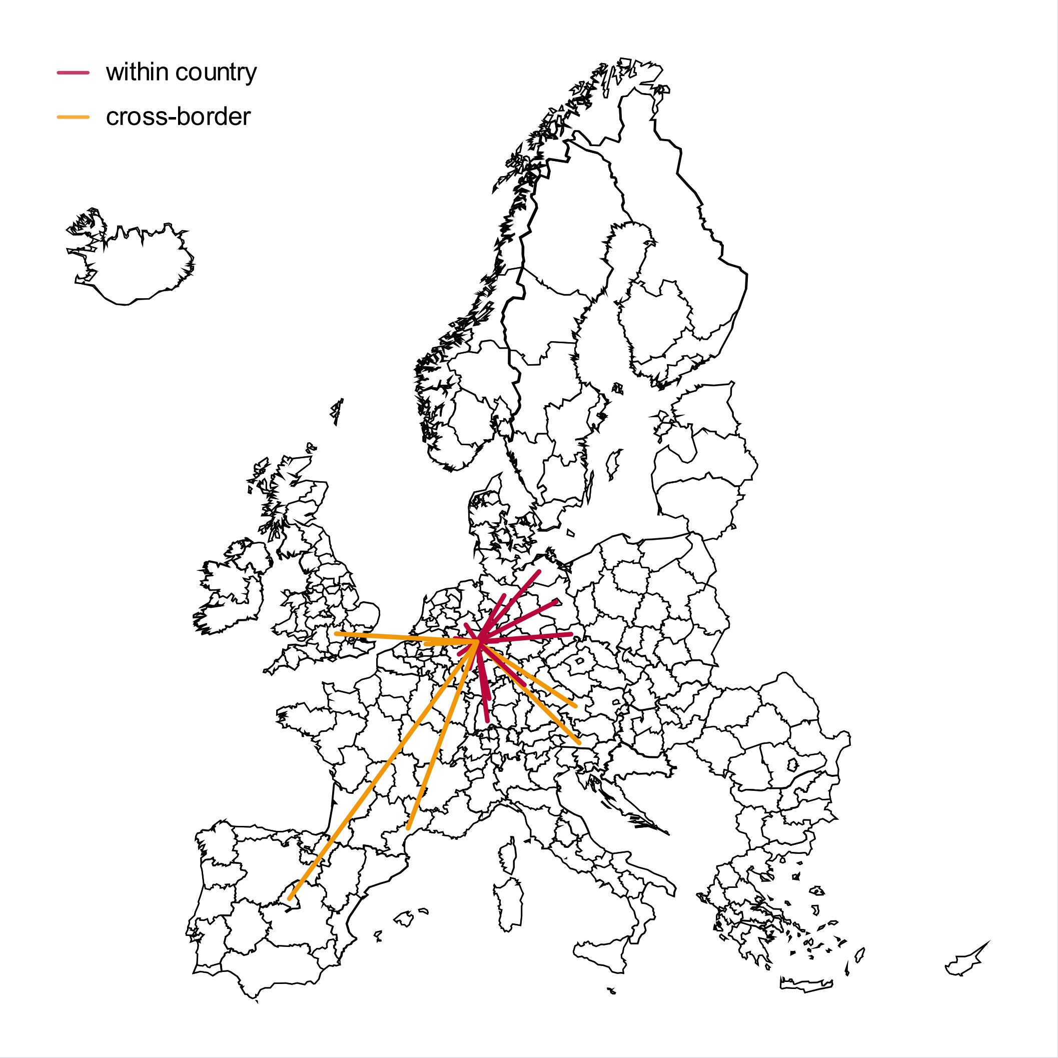
Figure 6: Inter-regional linkages of Länsi Suomi (Finland) in 5G



Notes: This map shows inter-regional collaborations of Länsi Suomi (FI19) for 5G technology. Linkages to NUTS-2 regions in Finland are coloured in red, linkages to NUTS-2 regions in other countries are shown in yellow. Source: OECD REGPAT, own calculation.

Figure 7 shows the inter-regional linkages of Arnsberg in Germany for hydrogen technology. For patents in this technology, Arnsberg currently cooperates in particular with other German regions like Düsseldorf, Münster, or Berlin. Cross-border linkages are recorded with regions in Austria, France, Belgium, Spain and the UK.

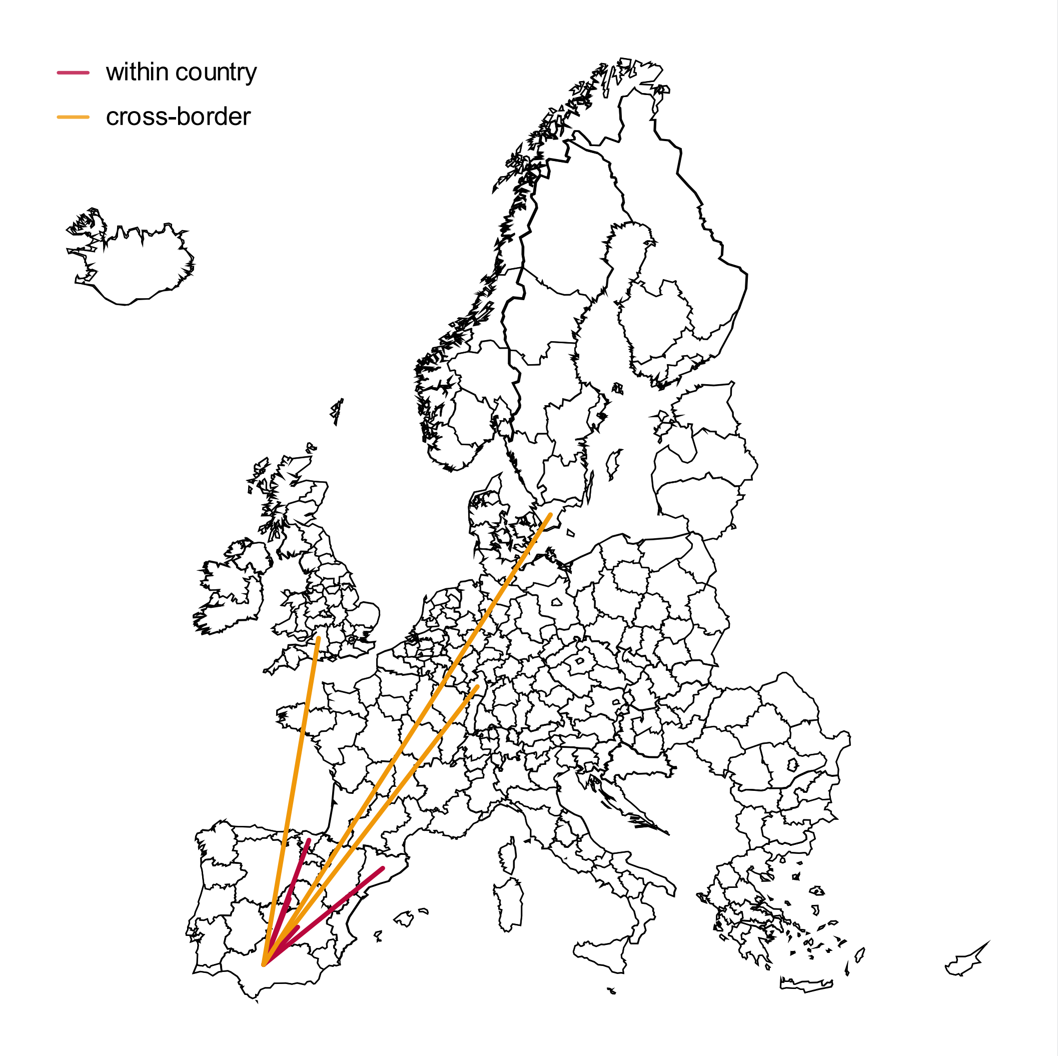
Figure 7: Inter-regional linkages of Arnsberg (Germany) in hydrogen



Notes: This map shows inter-regional collaborations of Arnsberg (DEA5) for hydrogen technology. Linkages to NUTS-2 regions in Germany are coloured in red, linkages to NUTS-2 regions in other countries are coloured in yellow. Source: OECD REGPAT, own calculation.

Figure 8 presents the inter-regional linkages of Andalucía (Spain) in virtual and augmented reality. In this technology, Andalucía has linkages with the Spanish regions Castilla-La Mancha, Comunidad de Madrid, País Vasco and Cataluña, as well as with Sydsverige in Sweden, Rheinhessen-Pfalz in Germany and Gloucestershire, Wiltshire and Bristol/Bath in the UK.

Figure 8: Inter-regional linkages of Andalucía (Spain) in virtual and augmented reality



Notes: This map shows inter-regional collaborations of Andalucía (ES61) for virtual and augmented reality technology. Linkages to NUTS-2 regions in Spain are coloured in red, linkages to NUTS-2 regions in other countries are shown in yellow. Source: OECD REGPAT, own calculation.

4 Potential for developing twin transition technologies and inter-regional cooperation in Europe

4.1 Potential of European regions for future technological advances

In Section 3.1, we looked at the current innovation activity of regions in twin transition technologies. To identify opportunities for regions to develop twin transition technologies in future, we use the framework of Balland et al. (2019). This framework is based on the concepts of relatedness and complexity (see above). The framework assesses whether a region's technological capabilities, as measured by patent output, are related to twin transition technologies. If a region has strong technological capabilities that require skills and knowledge matching those of a digital or green technology, the region has a higher chance of developing this technology. The complexity of a digital or green technology is proxied by its rarity and the wide range of capabilities that need to be combined to develop a twin transition technology. The underlying idea is that more complex technologies are harder to copy and, thus, generate higher economic returns. Therefore, regions will aim to develop complex twin transition technologies related to their existing technological capabilities.

To map the twin transition potentials of all European regions, we calculate so-called relatedness density scores[5] which measure the local presence of relevant capabilities. The relatedness density score sums the relatedness of a technology to all technologies (in which the region has an RCA higher than unity) and divides that by the sum of the relatedness of that technology to all other technologies in all European regions. The higher the relatedness density score, the higher the region's potential for developing the twin transition technology.

Figure 9 presents the potential of European regions to develop digital (left panel) and green technologies (right panel). It shows the average relatedness density score of a region for all digital and all green technologies. There are substantial differences across regions in these scores and, thus, their potential in developing further digital and green technologies. For digital technologies, more developed regions such as Oberbayern and Île-de-France stand out. In general, capital regions often exhibit a particularly high potential for developing technologies relevant for the digital transition. The relatedness density scores for green transition technologies are more concentrated. Many regions in Germany and some regions in Northern Italy exhibit the highest green relatedness density scores. By contrast, many regions in Eastern Europe as well as in the very north of Europe score lowest for relatedness density in green transition technologies.

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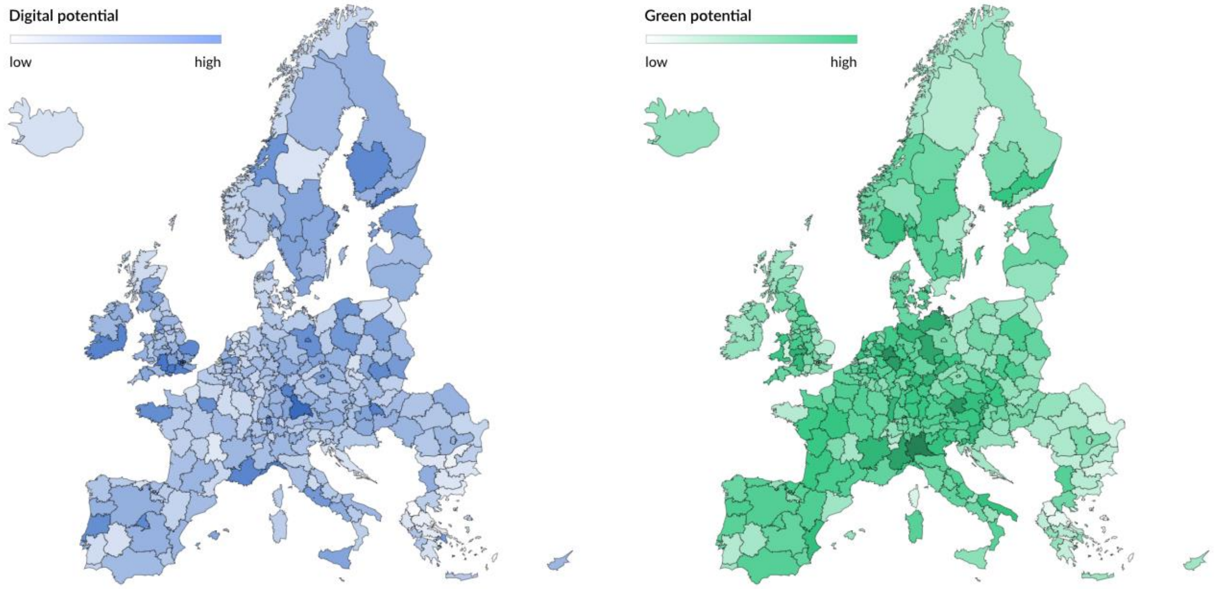
[5] Following Hidalgo et al. (2007) and Boschma et al. (2015), the density around technology *i* in region *r* at time *t* is derived from the technological relatedness of technology *i* to all other technologies *j* in which the region has a relative comparative advantage (RCA > 1) $\sum_{j \in r, j \neq i} \phi_{ijt}$ divided by the sum of technological relatedness of technology *i* to all other technologies *j* in all European regions at time $t \sum_{j \neq i} \phi_{ijt}$:

$$\text{RELATEDNESS DENSITY}_{i,r,t} = \frac{\sum_{j \in r, j \neq i} \phi_{ijt}}{\sum_{j \neq i} \phi_{ijt}} * 100$$

The relatedness density score is maximized when the region is specialised in all technologies technology *i* is related to.

Figure 9: Unequal potential of European regions to develop digital and green technologies



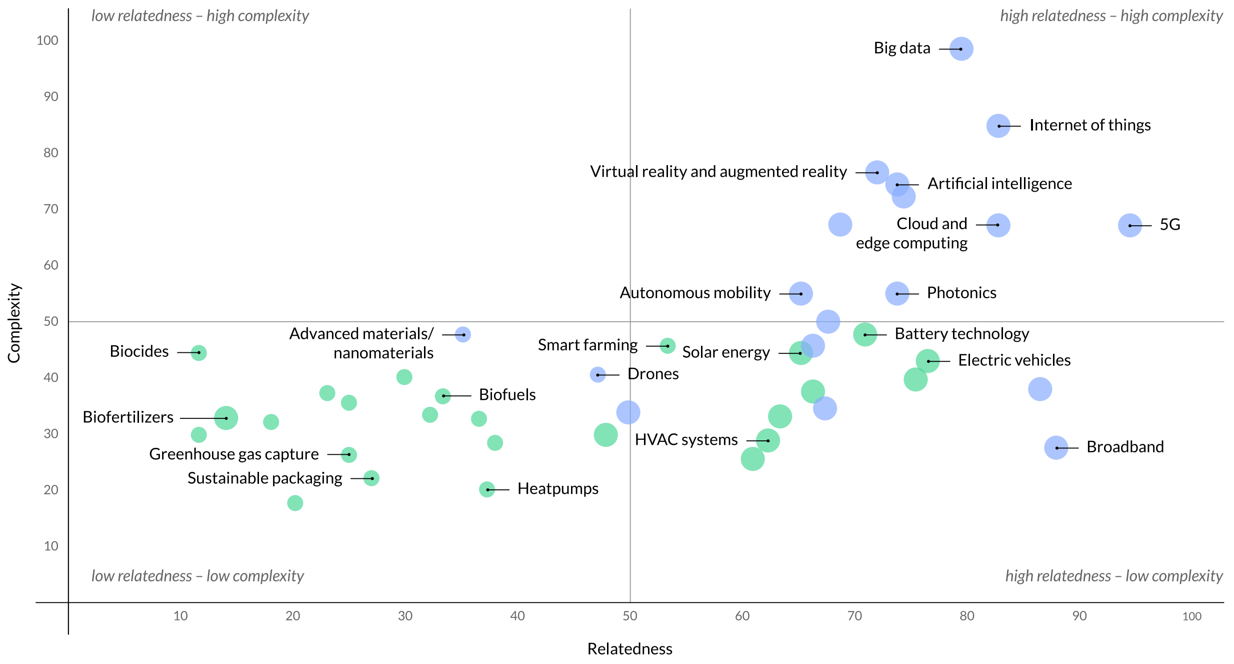
Notes: This figure shows the potential of European NUTS-2 regions to develop digital (left panel) and green (right panel) technologies in the future. The values used are relatedness density scores averaged across all digital and green technologies. A darker colour denotes a higher potential. Source: OECD REGPAT, own calculation.

To assess the implications for economic cohesion among EU regions, we analyse the relatedness of existing technological capabilities to digital and green technologies for more developed, transition and less developed regions. Additionally, we consider the complexity of each technology.[6] In Figures 10 to 12 we present the twin transition technology opportunities for each group of regions, with the relatedness to existing technologies on the horizontal axis and the level of complexity on the vertical axis. The blue nodes represent digital technologies, while the green nodes indicate green technologies. The size of the node illustrates regional comparative advantage (RCA) in this technology against all other regions. In principle, regions should aim to develop technologies of relatively high complexity which substantially match their technological capabilities gained from previous patenting activity.

Figure 10 shows the twin transition potential of the group of more developed EU regions. On average, more developed regions retain a high potential in various twin transition technologies. For digital technologies, the highest potential (based on capabilities gained from patenting activity) is found in complex technologies like 5G, internet of things, cloud and edge computing – and less so in low-complex digital technologies like advanced materials/nanomaterials. A similar picture emerges for green technologies: more developed regions demonstrate strong capabilities especially for electric vehicles, battery technology and solar energy. In general, the figure shows that the complexity of the green technologies with the highest potential is lower than for their digital counterparts.

[6] See Appendix A.4 for details on the concept of complexity and the complexity score estimated for each twin transition technology.

Figure 10: Potential of more developed EU regions to develop twin transition technologies

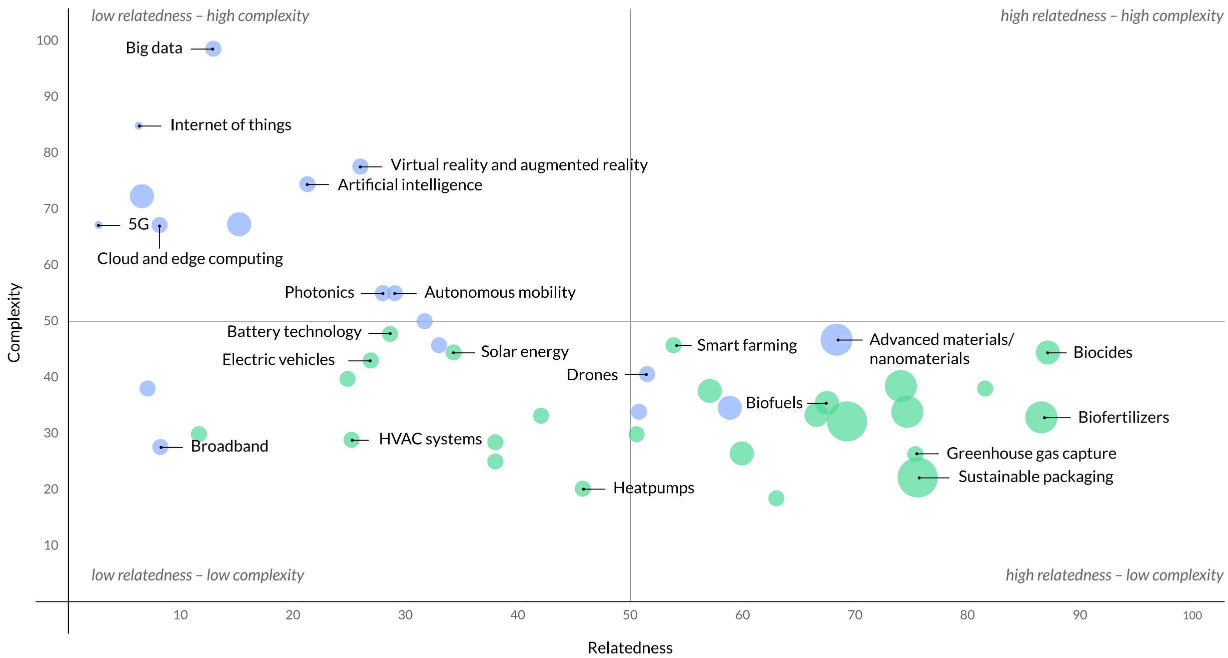


Notes: This figure shows the potential to develop twin transition technologies for the group of more developed regions in the EU. The horizontal axis plots the relatedness density score. The vertical axis plots the complexity scores (see Appendix A.4 for details on the complexity scores). All values are averaged across the group of more developed regions (for the classification of regions, see Appendix A.1). Source: OECD REGPAT, own calculation.

Figure 11 shows the potential of the group of transition regions in the EU. This pattern looks very different than that for more developed regions. Their potential to develop digital technologies is rather low for most technologies. Their highest potential in digital technologies is found in low-complex technologies, such as advanced materials/nanomaterials, additive manufacturing, drones and robotics. This reflects most probably the industrial tradition of many transition regions. Transition regions show high potential to develop green technologies such as biocides, biofertilizers, recycling technologies, advanced sustainable materials, waste management, greenhouse gas capture and sustainable packaging. Although the green technology potential is characterised by low complexity as compared to many digital technologies, it still may be beneficial for transition regions to go for green technologies.

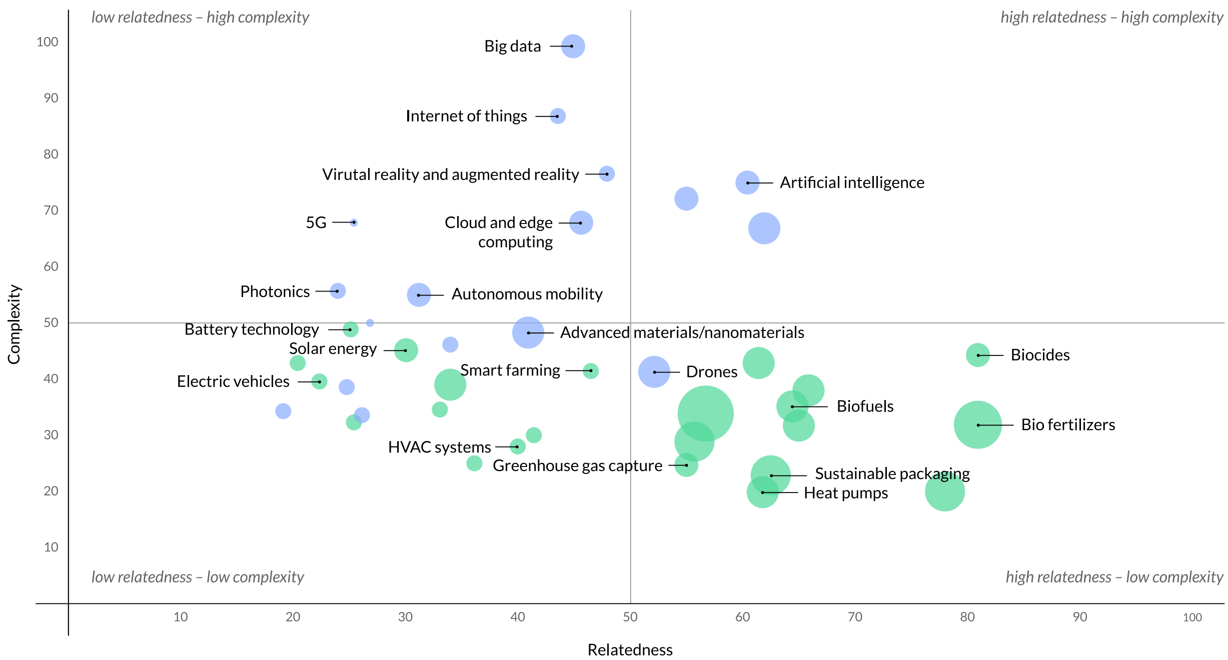
Figure 12 maps the potential for the group of less developed regions in the EU. They have the highest potential in green technologies, in particular biocides, biofertilizers, and geothermal energy, in waste management, recycling technologies, biofuels and fuels from waste. Their potential for relatively complex digital technologies is rather limited, with some notable exceptions such as AI or cryptography and distributed ledger technology. In general, this group of regions is characterized by a low level of patent activity in twin transition technologies (see Section 3.1), which brings a significant disadvantage as compared to other regions. They could even so benefit from a focus on research and innovation targeted at fostering the green transition.

Figure 11: Potential of EU transition regions to develop twin transition technologies



Notes: This figure shows the potential to develop twin transition technologies for the group of transition regions in the EU. The horizontal axis plots the relatedness density score. The vertical axis plots the complexity scores (see Appendix A.4 for details on the complexity scores). All values are averaged across the group of transition regions (for the classification of regions, see Appendix A.1). Source: OECD REGPAT, own calculation.

Figure 12: Potential of less developed EU regions to develop twin transition technologies



Notes: This figure shows the potential to develop twin transition technologies for the group of less developed regions in the EU. The horizontal axis plots the relatedness density score. The vertical axis plots the complexity scores (see Appendix A.4 for details on the complexity scores). All values are averaged across the group of less developed regions (for the classification of regions, see Appendix A.1). Source: OECD REGPAT, own calculation.

EU regions with high potential to develop twin transition technologies

Table 8 provides examples of regions with a particularly high potential to develop twin transition technologies based on the relatedness to their previous technological activity. Each income group of regions has its stand outs. We present the twin transition technology potential for all European regions in Appendix A.6.

Table 8: Regions with high potential to develop green and digital (or both) technologies

High relatedness with technologies	**More developed regions**	**Transition regions**	**Less developed regions**
digital and green	DE21 Oberbayern	FR82 Provence-Alpes-Côte d'Azur	ES61 Andalucía
digital only	SE11 Stockholm	FR52 Bretagne	ITG1 Sicilia
green only	DEB3 Rheinhessen-Pfalz	FR24 Centre	PT11 Norte

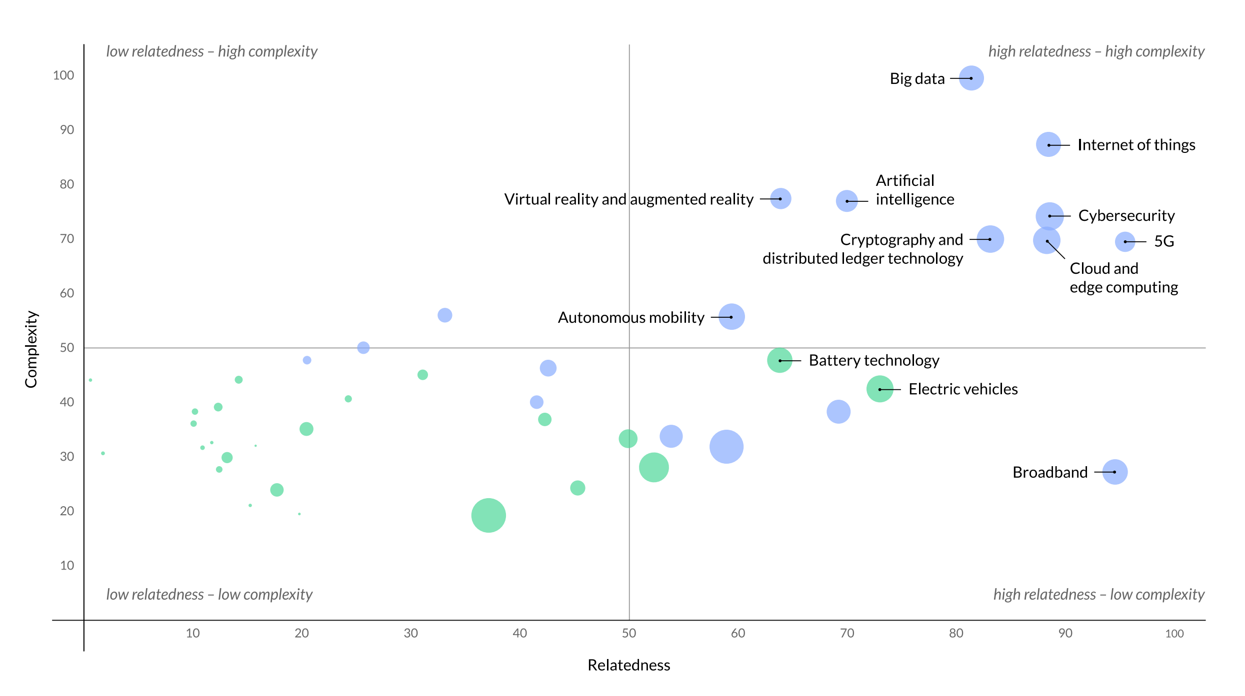
Notes: This table lists for each group of regions the region with a particularly high potential to develop digital, green or both types of technologies. The selected regions have technological capabilities highly related (i.e., relatedness density score within the top decile per group of technologies) to previous patenting activity and an above-average number of digital/green patents. The table lists the region with the highest number of patents. Source: OECD REGPAT, own calculation.

In the following, we provide examples for the opportunities to develop twin transition technologies for the regions of Oberbayern in Germany, Centre in France and Sicilia in Italy.

We start with Oberbayern. Figure 13 shows a high potential to develop complex digital technologies such as big data, internet of things, 5G, cloud and edge computing or AI. This is the result of a cluster of software firms in Munich and its surroundings. Oberbayern, as home to a large automotive and engineering sector, also displays strong potential for developing green technologies like electric vehicles and battery technology. Overall, Oberbayern is almost certain to develop multiple technologies of complex nature relevant for the twin transition.

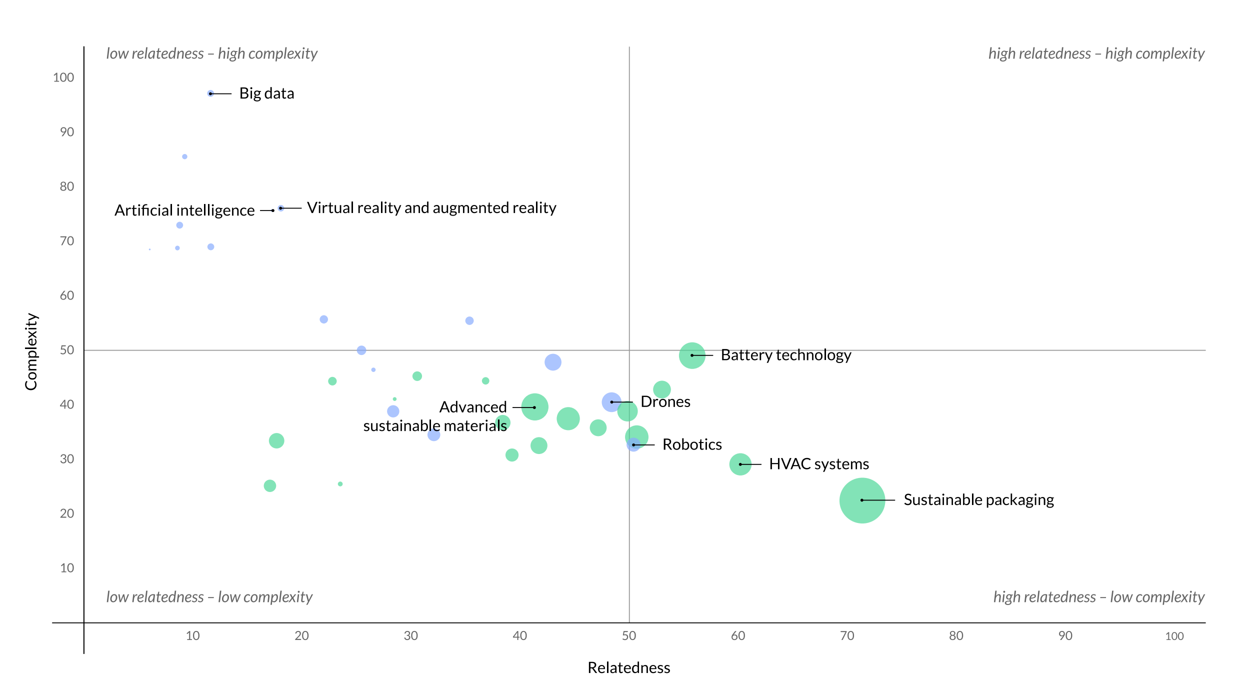
Next, we look at the twin transition potential of Centre. Figure 14 shows strong capabilities in the green technologies of sustainable packaging and HVAC systems – highly related to previous innovation activity in this region. This is unsurprising as pharmaceuticals, transport and food processing are key industry sectors for Centre, which all rely on (sustainable) packaging and HVAC. As for digital technologies: robotics and drones as well as advanced materials/nanomaterials are most related to current innovation activities. The opportunities in more complex technologies such as virtual & augmented reality, AI or big data are limited given the low level of previous patenting activities in relevant fields.

Figure 13: Opportunities for twin transition technologies in Oberbayern (Germany)



Notes: This figure shows the potential to develop twin transition technologies for Oberbayern (DE21) in Germany. The horizontal axis plots the relatedness density scores for twin transition technologies. the vertical axis plots the complexity scores of twin transition technologies (see Appendix A.4 for details on the complexity scores for twin transition technologies). Source: OECD REGPAT, own elaboration.

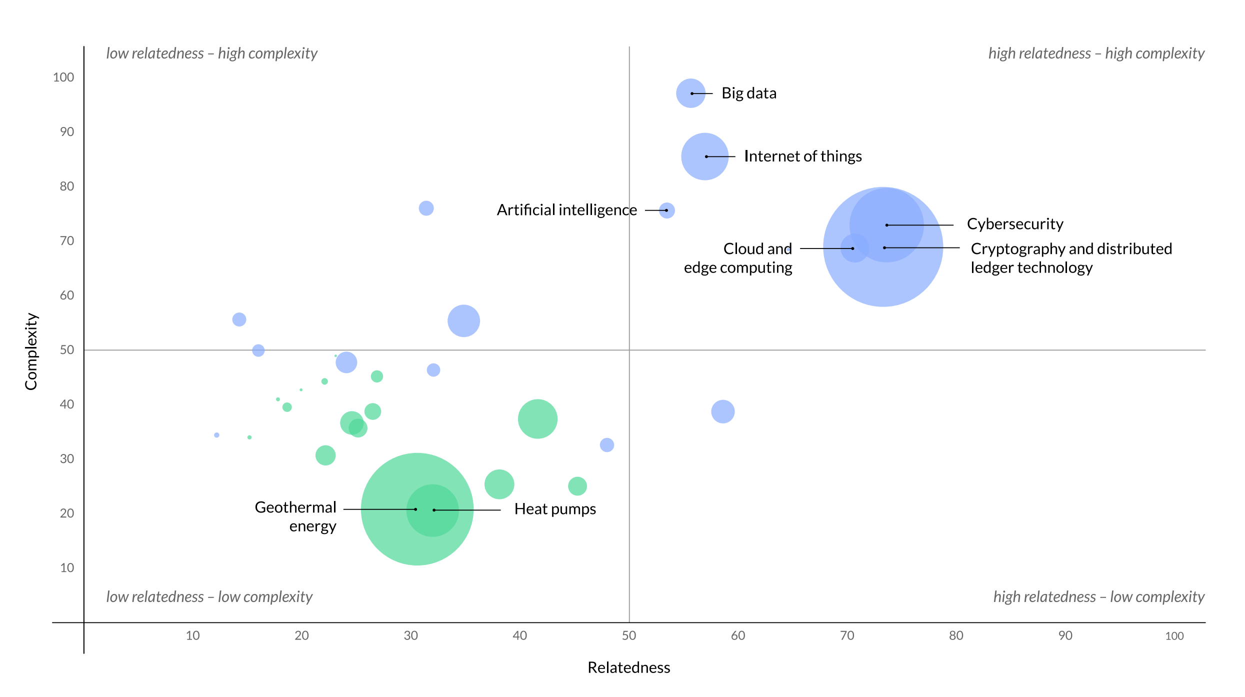
Figure 14: Opportunities for twin transition technologies in Centre (France)



Notes: This figure shows the potential to develop twin transition technologies for Centre (FR24) in France. The horizontal axis plots the relatedness density scores for twin transition technologies. the vertical axis plots the complexity scores of twin transition technologies (see Appendix A.4 for details on the complexity scores for twin transition technologies). Source: OECD REGPAT, own elaboration.

Finally, we analyse the twin transition potential for Sicilia. Figure 15 reveals a relatively high potential for developing complex digital technologies like cybersecurity, cryptography & distributed ledger technology as well as cloud and edge computing. These technologies are highly related with the region's previous innovation activity. A major contributor here is likely the ICT company Italtel which runs a major research hub near Palermo. Recent patenting activity in Sicilia does not suggest strong potential for developing complex green technologies.

Figure 15: Opportunities for twin transition technologies in Sicilia (Italy)



Notes: This figure shows the potential to develop twin transition technologies for Sicilia (ITG1) in Italy. The horizontal axis plots the relatedness density scores for twin transition technologies. the vertical axis plots the complexity scores of twin transition technologies (see Appendix A.4 for details on the complexity scores for twin transition technologies). Source: OECD REGPAT, own elaboration.

4.2 Untapped potential for inter-regional cooperation in Europe

So far, we have looked at relevant capabilities in a region (relatedness density) to assess regional potential for developing twin transition technologies. However, a region that lacks these relevant capabilities may also connect to other regions to gain access to them. Balland and Boschma (2021b) showed for European regions that so-called *complementary capabilities* in other regions may well enhance the potential of regions to diversify into new technologies. This idea is still underdeveloped in thinking about building partnerships in regional innovation in Europe (Pontikakis et al. 2022).

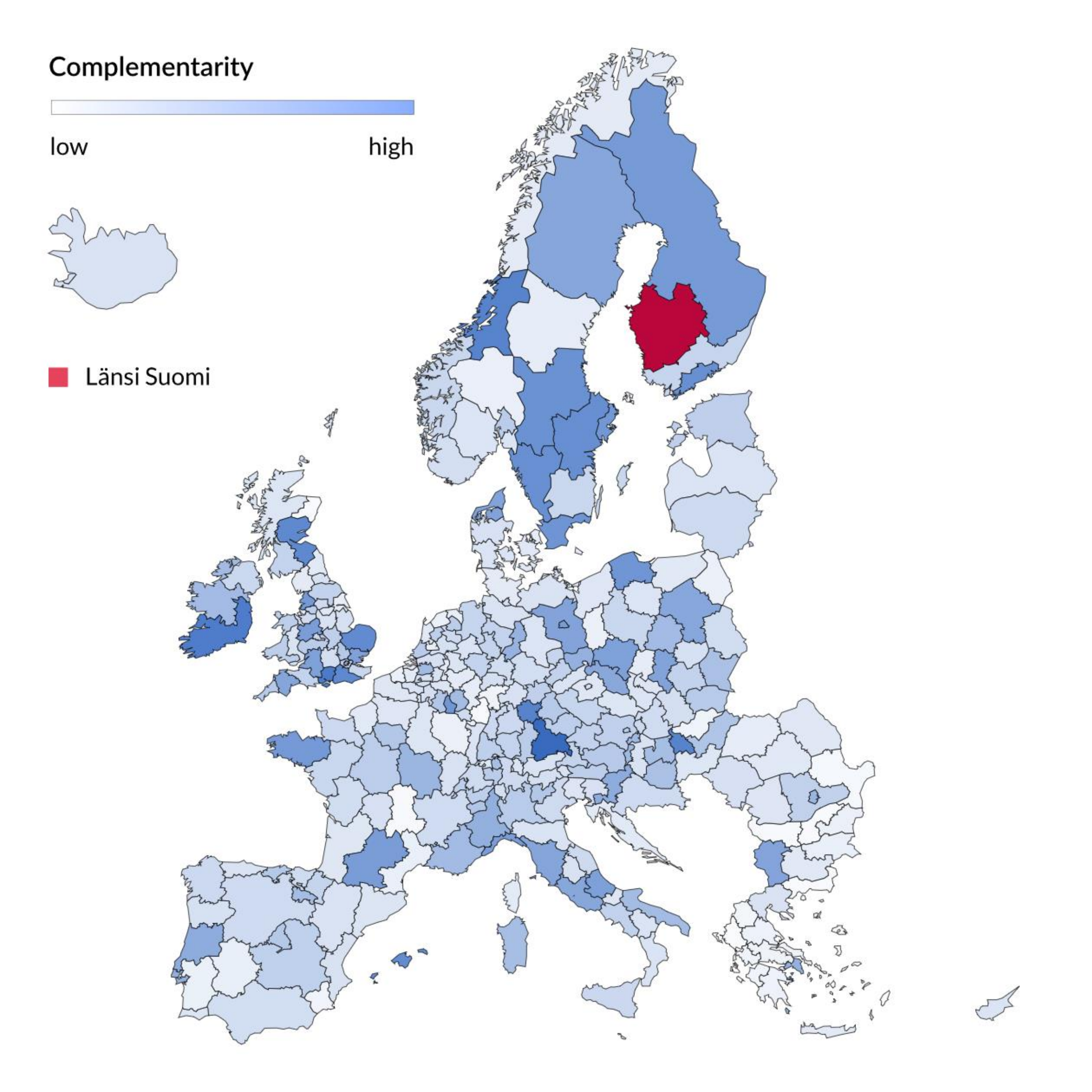
But with which partners should regions collaborate? Balland and Boschma (2021b) develop the concept of complementarity, which refers to the search for capabilities in other regions that are absent at home. Accessing these capabilities through inter-regional collaboration may increase the potential of home regions to diversify into specific new technologies. Balland and Boschma (2021b) provide a complementarity measure to identify, for a region, relevant capabilities in other regions that are lacking at home but complementary to the technology the region aims to develop. Basically, it measures the relatedness density that each region could add to the current relatedness density of the region for a particular technology. We use this complementarity indicator to identify for each green and each digital technology which are the most important regions that could provide complementary capabilities to a region ("added" relatedness density) to develop this technology. For example, Region A might have a relatedness density of 50 for solar energy. Region B has a relatedness density of 20 in related technologies absent in Region A. When connecting to Region B, Region A would add 20 to its 50 relatedness density score, thereby substantially increasing its potential for developing solar energy.

Three regions, three technologies: Examples of technological complementarities for selected EU regions

In the following, we present complementarity maps for three regions which have not yet developed a specific twin transition technology. Complementarity maps show the degree of capabilities in other regions that are absent at home to diversify into this new technology.

Figure 16 shows the complementarity map of Länsi Suomi in Finland for 5G technology: the region could connect with other Finnish regions like Helsinki-Uusima to access complementary capabilities, but other relevant partners are located mainly outside Finland. Regions with a high fit for Länsi Suomi in 5G are found in other Scandinavian countries (especially Sweden), in Germany (in Oberbayern and Mittelfranken in particular), and in Southern and Eastern Ireland. All these regions could help Länsi Suomi develop a new specialisation in 5G.

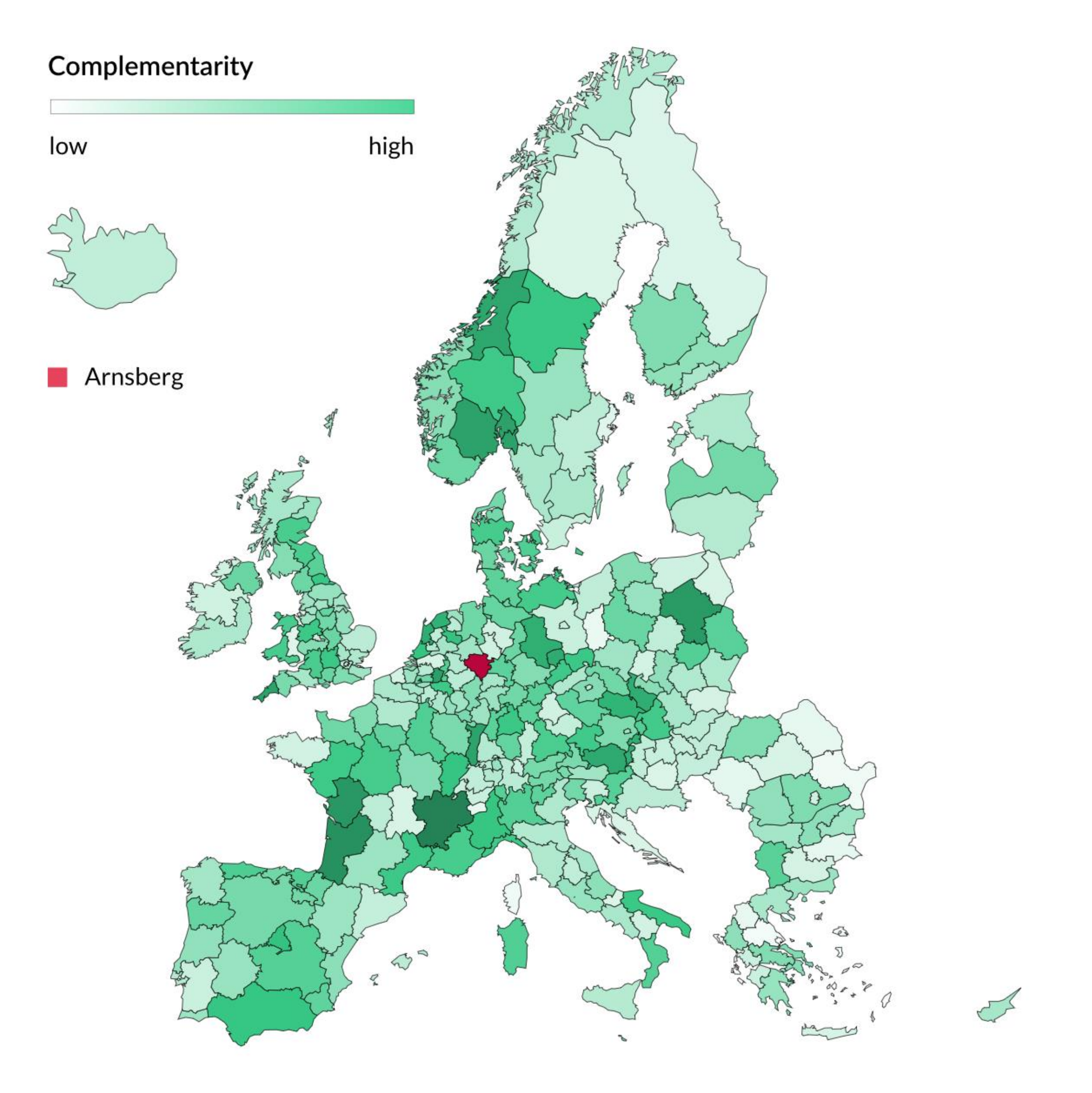
Figure 16: Complementarity map of Länsi Suomi (Finland) for 5G



Notes: This map shows European NUTS-2 regions with complementary technological capabilities to Länsi Suomi (FI19, coloured in red) to develop 5G technology. High values denote a high complementarity (measured in “added” relatedness density) and, thus, a high potential for Länsi Suomi to develop the technology when collaborating with the respective region. Source: OECD REGPAT, own calculation.

Figure 17 shows complementary regions for Arnsberg in Germany for hydrogen technology. Arnsberg has a wide range of potential partner regions to choose from for accessing complementary capabilities. To develop this green technology, it could partner up with neighbouring German regions, such as Leipzig and Sachsen-Anhalt. But relevant partners also exist in other countries such as France or the Netherlands.

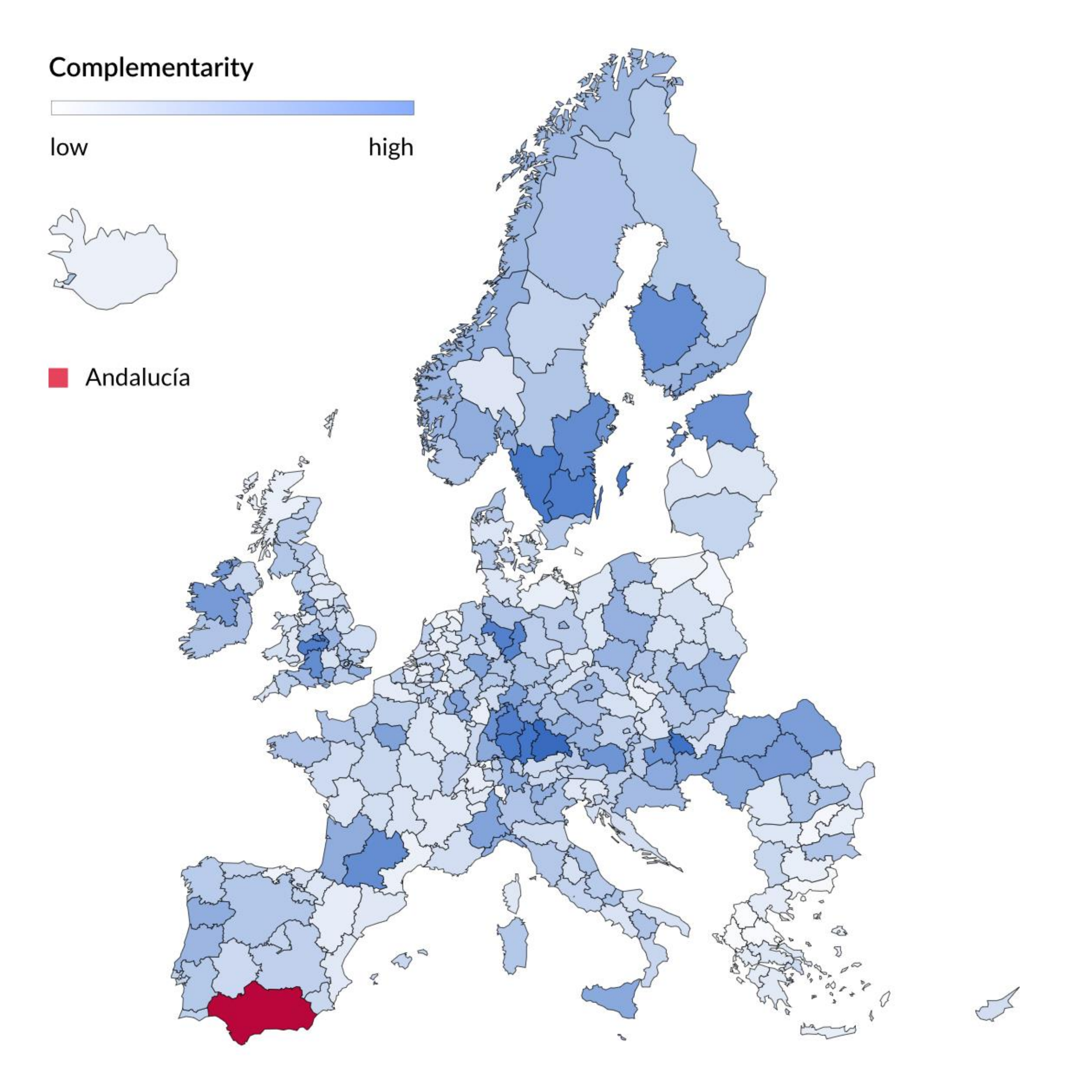
Figure 17: Complementarity map of Arnsberg (Germany) for hydrogen



Notes: This map shows European NUTS-2 regions with complimentary technological capabilities to Arnsberg (DEA5, coloured in red) to develop hydrogen technology. High values denote a high complementarity (measured in “added” relatedness density) and, thus, a high potential for Arnsberg to develop the technology when collaborating with the respective region. Source: OECD REGPAT, own calculation.

Figure 18 shows the complementarity map of Andalucía in Spain for virtual and augmented reality technology. The map shows that Spanish regions have little relevant capabilities to offer. Regions with relevant capabilities are for example Oberbayern, Île-de-France, Stockholm or Länsi Suomi.

Figure 18: Complementarity map of Andalucía (Spain) for virtual and augmented reality



Notes: This map shows European NUTS-2 regions with complimentary technological capabilities to Andalucía (ES61, coloured in red) to develop virtual and augmented reality technology. High values denote a high complementarity (measured in “added” relatedness density) and, thus, a high potential for Arnsberg to develop the technology when collaborating with the respective region. Source: OECD REGPAT, own calculation.

The complementarity between the capabilities of two regions with respect to a specific technology is an important factor determining the potential of a collaboration to develop a certain technology. If the two regions' capabilities were perfectly complementary in meeting the requirements for developing a specific technology, this could point to a potentially fruitful cooperation.

As discussed in Section 3.2, most inter-regional linkages occur between regions within the same country. Furthermore, we find that all three groups of EU regions most often collaborate with the more developed ones with the largest patent output in twin transition technologies. Thus, factors such as geographical distance and size of patent output, but also gradations in relatedness of regional capabilities to a technology a region wishes to develop are expected to influence collaboration between the two. However, it may be that the sizeable proportion of inter-regional linkages within countries reflects a limited search for and knowledge about potential matching innovation partners in other countries.

To estimate the untapped potential between regions, we compare the actual inter-regional network with an ideal network predicted by an extended gravity model that integrates real-world constraints (geographical distance, the total number of patent outputs in each region pair, relatedness density of both regions around a certain technology, and the gap in relatedness density between them) as well as complementarity linkages.[7] To assess the untapped potential in collaboration between each regional pair, we subtract the number of realised linkages between two regions from the ideal number of linkages predicted by the model considering complementarity.[8] A large score indicates a large untapped potential.

The following two figures show for each EU region the three inter-regional linkages with the highest untapped potential score for digital technologies (Figure 19) and green technologies (Figure 20). A linkage potential within the same country is coloured in red, a cross-border linkage potential in yellow. Both figures demonstrate that the highest untapped potential for inter-regional collaboration in the EU is found cross-border. This is a completely different picture than the one we found in Figures 4 and 5 for inter-regional collaborations now in place, where we see a clear national bias.

Results indicate that there is substantial untapped potential in inter-regional collaboration when it comes to development of twin transition technologies. This is the case for all three groups of regions, implying that all type of regions could benefit considerably from further inter-regional collaboration in developing digital and green technologies.

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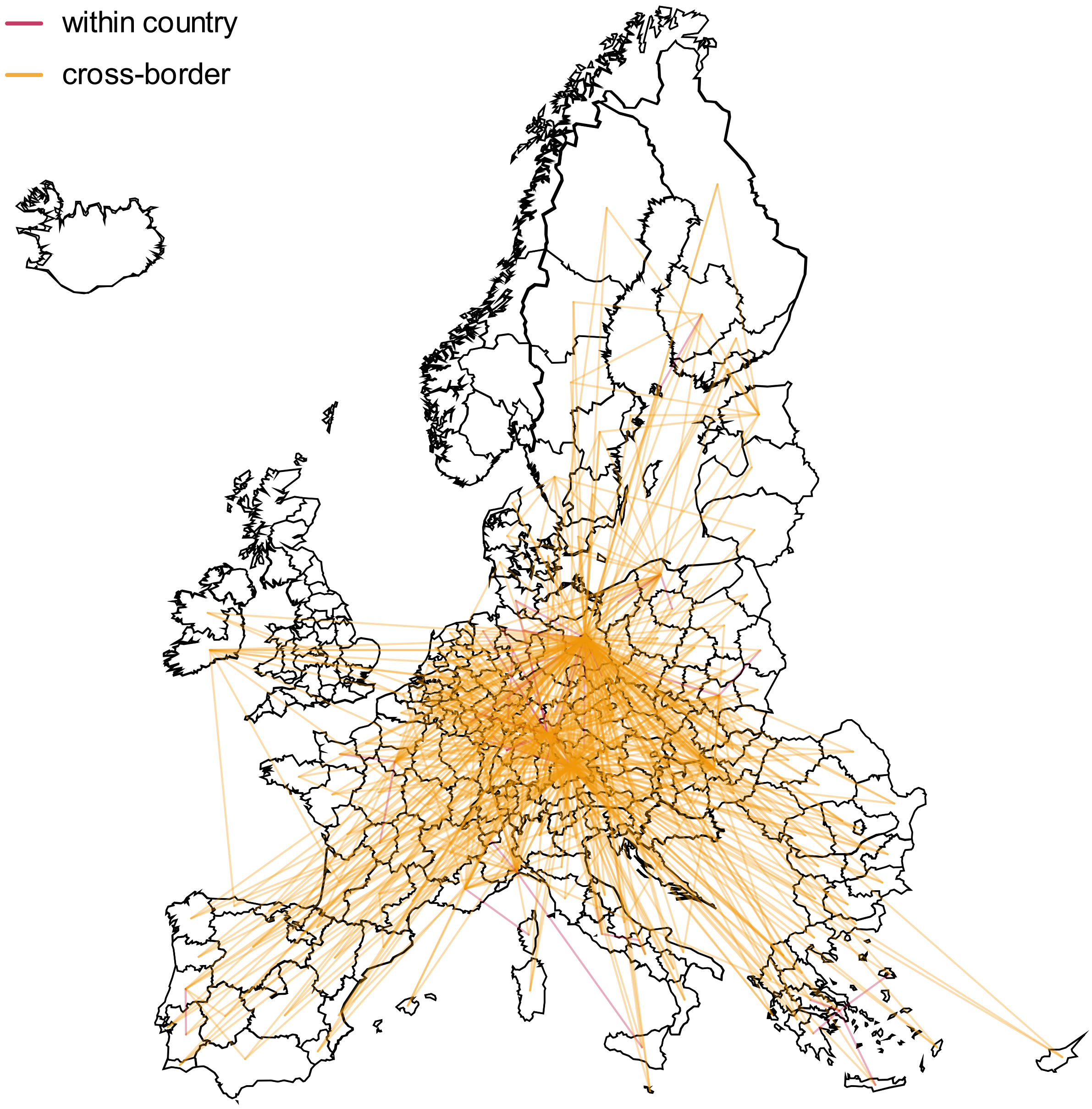
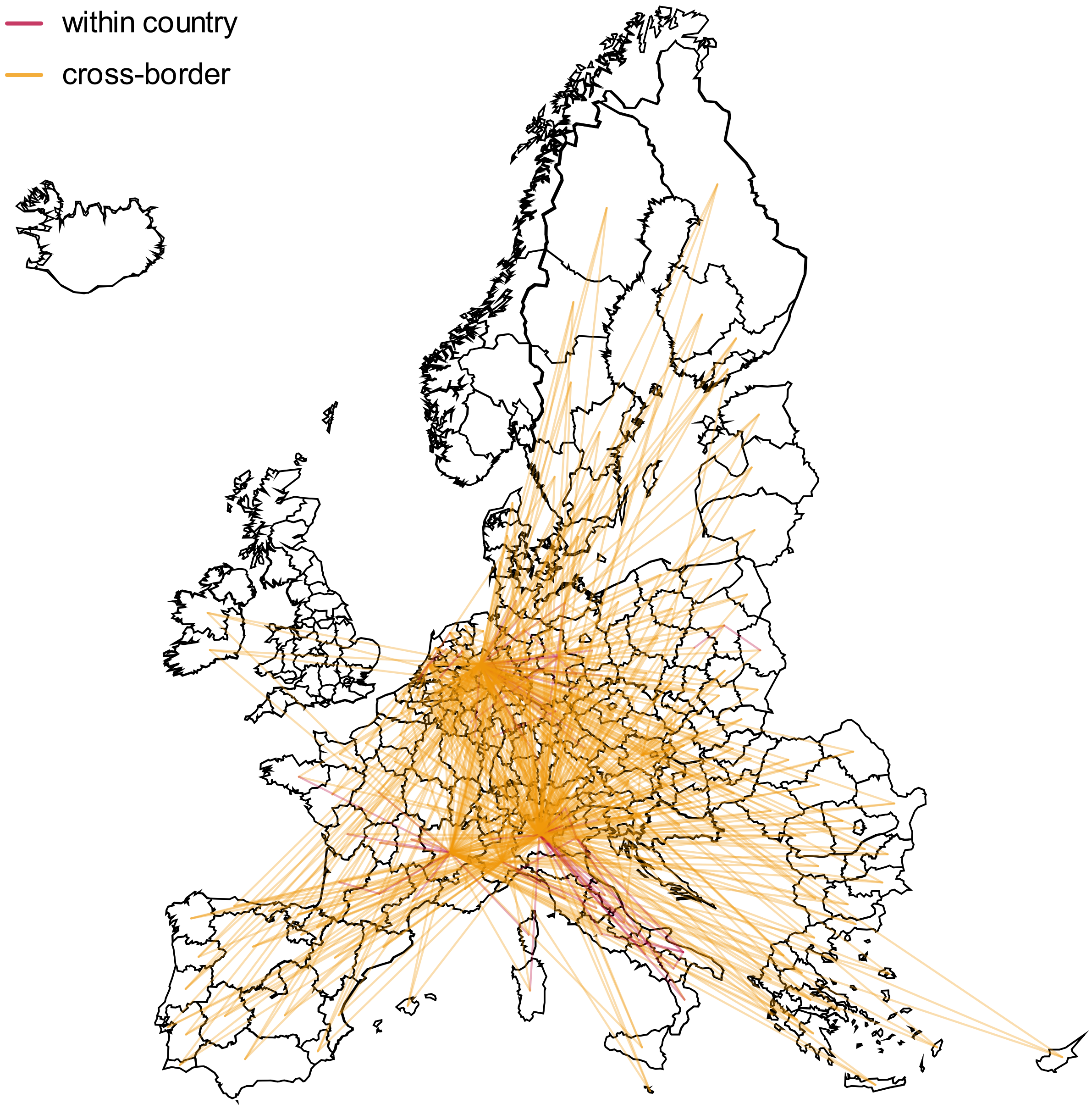
[7] Appendix A.6 provides methodological details of the extended gravity model.
[8] Given the differences in the absolute number of realised linkages, both numbers are normalised.

Figure 19: Highest untapped potential for inter-regional collaboration in digital technologies between EU regions



Notes: This map shows for each EU NUTS-2 region the three inter-regional linkages with the highest untapped potential score for digital technologies. See Appendix A.4 for a detailed description of the methodology. Linkage potential within the same EU country is coloured in red, cross-border linkage potential in yellow. Source: OECD REGPAT, own elaboration.

Figure 20: Highest untapped potential for inter-regional collaboration in green technologies between EU regions



Notes: This map shows for each EU NUTS-2 region the three inter-regional linkages with the highest untapped potential score for green technologies. See Appendix A.4 for a detailed description of the methodology. Linkage potential within the same EU country is coloured in red, cross-border linkage potential in yellow. Source: OECD REGPAT, own elaboration.

EU regions with highest untapped potential for inter-regional collaboration

We assess the untapped potential of EU regions for collaborations using an extended gravity model (for methodological details, see Appendix A.4). We estimate for all regional pairs untapped potential scores. The higher the untapped potential score, the more missed opportunities to collaborate a region has.

In Table 9, we list the regions with the highest average untapped potential for inter-regional collaboration in digital technologies. In the group of more developed regions, Luxembourg is found to have the highest unexploited potential to connect with other regions to access complementary capabilities. Vorarlberg in Austria and Prov. Antwerpen in Belgium also leave many opportunities untapped. Among transition regions, Dolnośląskie in Poland ranks number one in terms of untapped potential, followed by Střední Čechy in Czechia and Brandenburg in Germany. The group of less developed regions with the highest untapped inter-regional collaboration potential is led by Nyugat-Dunántúl in Hungary, Prov. Luxembourg in Belgium and Közép-Dunántúl in Hungary.

Table 9: EU regions with highest untapped potential for inter-regional collaboration in digital technologies

	More developed regions		Transition regions		Less developed regions	
#	**Region**	**Score**	**Region**	**Score**	**Region**	**Score**
1	LU00 Luxembourg	43.9	PL51 Dolnośląskie	43.8	HU22 Nyugat-Dunántúl	43.0
2	AT34 Vorarlberg	43.5	CZ02 Střední Čechy	43.5	BE34 Prov. Luxembourg (BE)	42.8
3	BE21 Prov. Antwerpen	43.5	DE40 Brandenburg	42.9	HU21 Közép-Dunántúl	42.6
4	DE22 Niederbayern	43.2	FR41 Lorraine	42.6	CZ05 Severovýchod	42.5
5	SE23 Västsverige	43.0	BE35 Prov. Namur	42.6	CZ04 Severozápad	42.4

Notes: This table lists the EU NUTS-2 regions with the highest average untapped potential for collaborating with other regions in digital technologies for the three groups of regions (see Appendix A.4 for a detailed description of the methodology applied). Source: OECD REGPAT, own calculation.

Table 10 lists the regions with the highest average untapped potential for inter-regional collaboration in green technologies. The Top 5 group of more developed regions with highest untapped potential is dominated by German regions, namely Hannover, Niederbayern and Köln. The transition region with the highest untapped potential for collaboration is Thüringen in Germany, followed by Franche-Comté in France and Střední Čechy in Czechia. Most untapped potential for inter-regional collaboration among less developed regions is found for Jadranska Hrvatska in Croatia and the Romanian regions Vest, Centru and Nord-Vest.

Table 10: EU regions with highest untapped potential for inter-regional collaboration in green technologies

	More developed regions		Transition regions		Less developed regions	
#	Region	Score	Region	Score	Region	Score
1	DE92 Hannover	44.9	DEG0 Thüringen	44.3	HR03 Jadranska Hrvatska	42.6
2	SE11 Stockholm	44.8	FR43 Franche-Comté	43.2	RO42 Vest	41.9
3	NL41 Noord-Brabant	44.6	CZ02 Střední Čechy	42.6	RO12 Centru	41.9
4	DE22 Niederbayern	44.2	FR83 Corse	41.7	RO11 Nord-Vest	41.5
5	DEA2 Köln	44.1	FR52 Bretagne	41.6	PL42 Zachodniopomorskie	41.5

Notes: This table lists the EU NUTS-2 regions with the highest average untapped potential for collaborating with other regions in green technologies for the three groups of regions (see Appendix A.4 for a detailed description of the methodology applied). Source: OECD REGPAT, own calculation.

The untapped potential for inter-regional collaborations in twin transition technologies is pretty well equally distributed across the three different regional groups, as Table 11 reveals. All groups of regions have relatively higher untapped potential with more developed regions and lower untapped potential with less developed ones. Table 11 also indicates on average a higher untapped potential for cross-border collaborations for each group of regions.

Table 11: Average untapped potential score for inter-regional linkages in the EU by groups of regions

	Untapped potential with other regions			Untapped potential for linkages	
	more developed	transition	less developed	within country	cross-border
More developed regions	43.6	42.2	35.9	35.6	41.2
Transition regions	43.7	40.2	33.3	38.0	39.6
Less developed regions	43.5	39.4	33.2	37.5	39.2

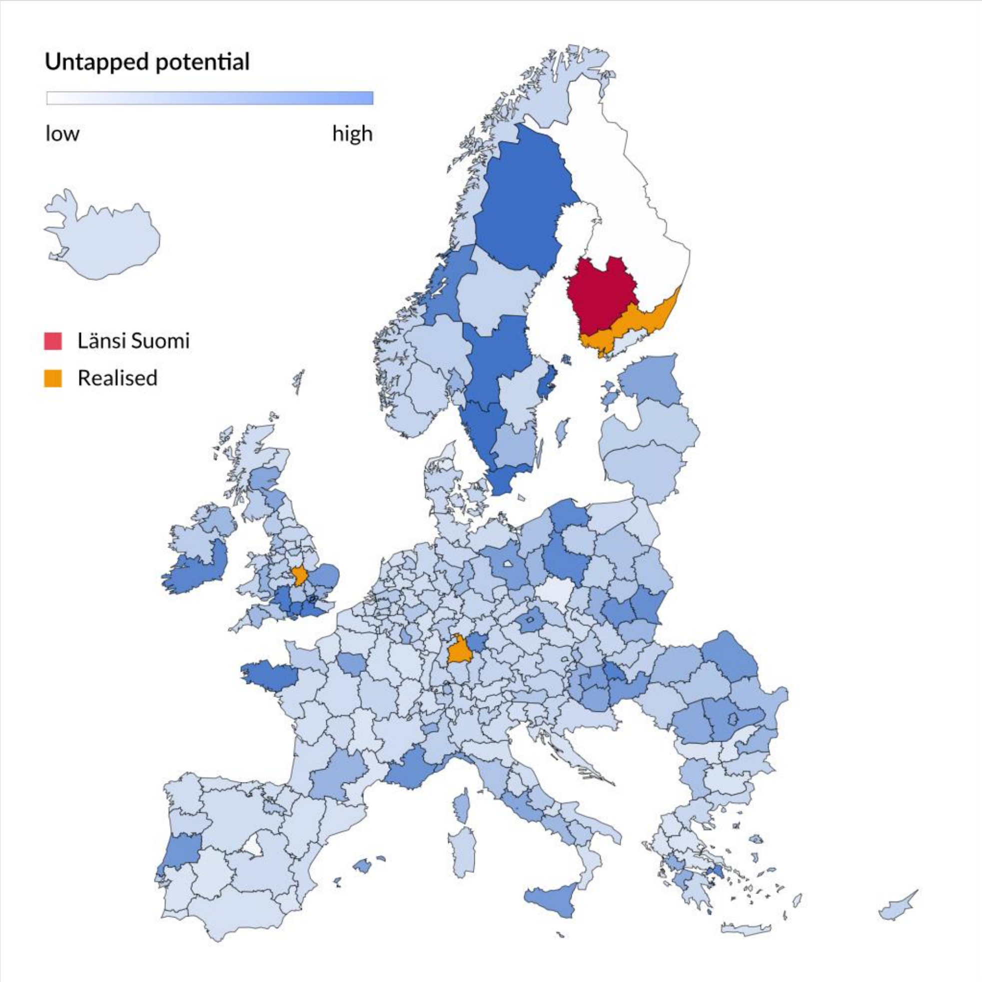
Notes: The table shows the average untapped potential scores for different groups of partner regions by group of regions as well as within country and cross-border linkages. Appendix A.4 provides a detailed description of the methodology used for determining untapped potential. Source: OECD REGPAT, own elaboration.

Untapped potential for inter-regional collaboration in European regions

The untapped potential for inter-regional cooperation to develop twin transition technologies varies substantially across regions and technologies. In the following, we present three regional examples of untapped potential in specific technologies. The untapped potential score is calculated using our extended gravity model (as detailed in Appendix A.4).

Figure 21 presents the untapped potential for inter-regional linkages for the Finnish region of Länsi Suomi in 5G technology. In Länsi Suomi's case, the highest potential for collaboration is predicted for the region of Helsinki-Uusima. Indeed, this potential is realised as Länsi Suomi already cooperates with this region in 5G. However, the region could also cooperate with additional regions in developing 5G technology, for example with Stockholm – with the second highest potential score – and three other Swedish regions as well as with Oberbayern in Germany or Bretagne in France.

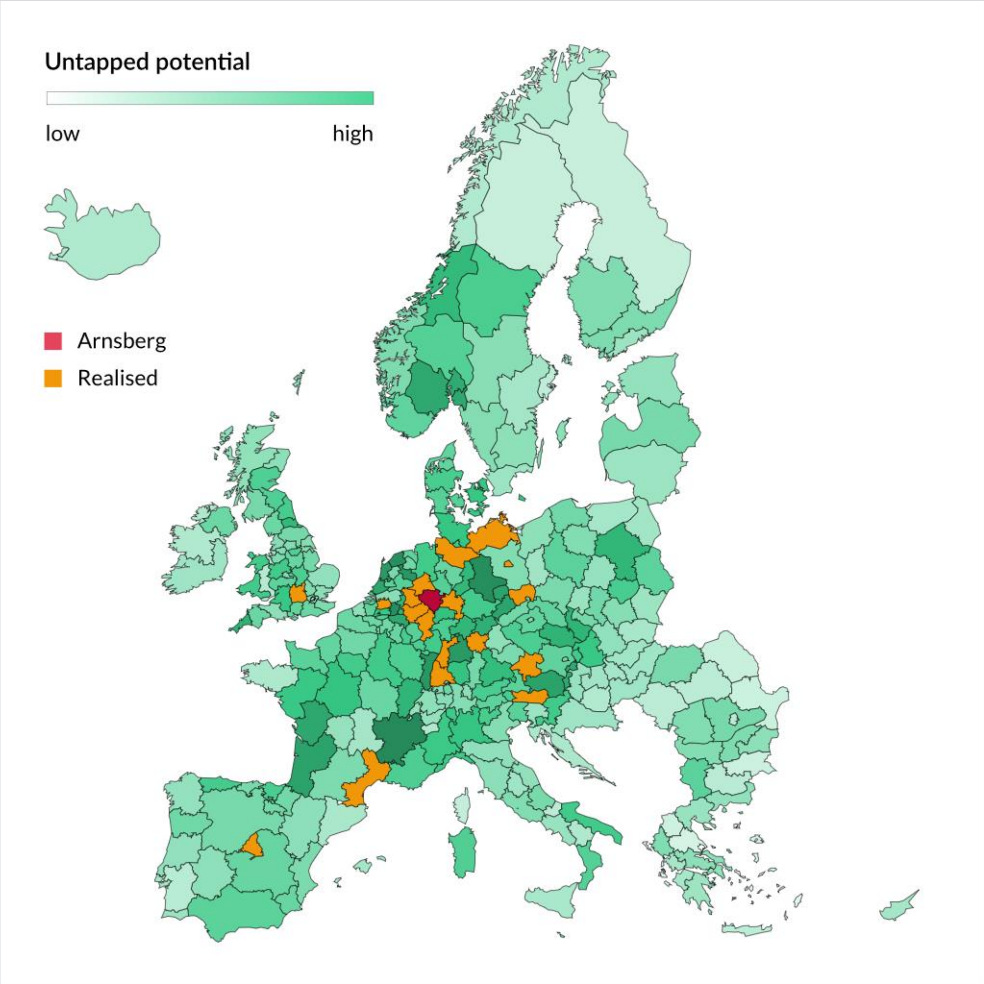
Figure 21: Untapped potential for inter-regional collaborations for Länsi Suomi (Finland) in 5G



Notes: This map shows the untapped potential score for inter-regional collaboration of Länsi Suomi (FI19, coloured in red) with European regions in 5G technology. Appendix A.4 provides a detailed description of the methodology. Already realised inter-regional collaborations are coloured in orange. Source: OECD REGPAT, own calculation.

Figure 22 shows the untapped potential in inter-regional cooperation for Arnsberg, Germany, in hydrogen technology. Arnsberg does not exploit yet the considerable potential it could get from collaborating with regions like Brussels in Belgium, Rhône-Alpes in France and the German region of Sachsen-Anhalt, for which the model predicts the highest number of linkages. Further promising collaboration partners are located in the Netherlands as well as in other French and German regions.

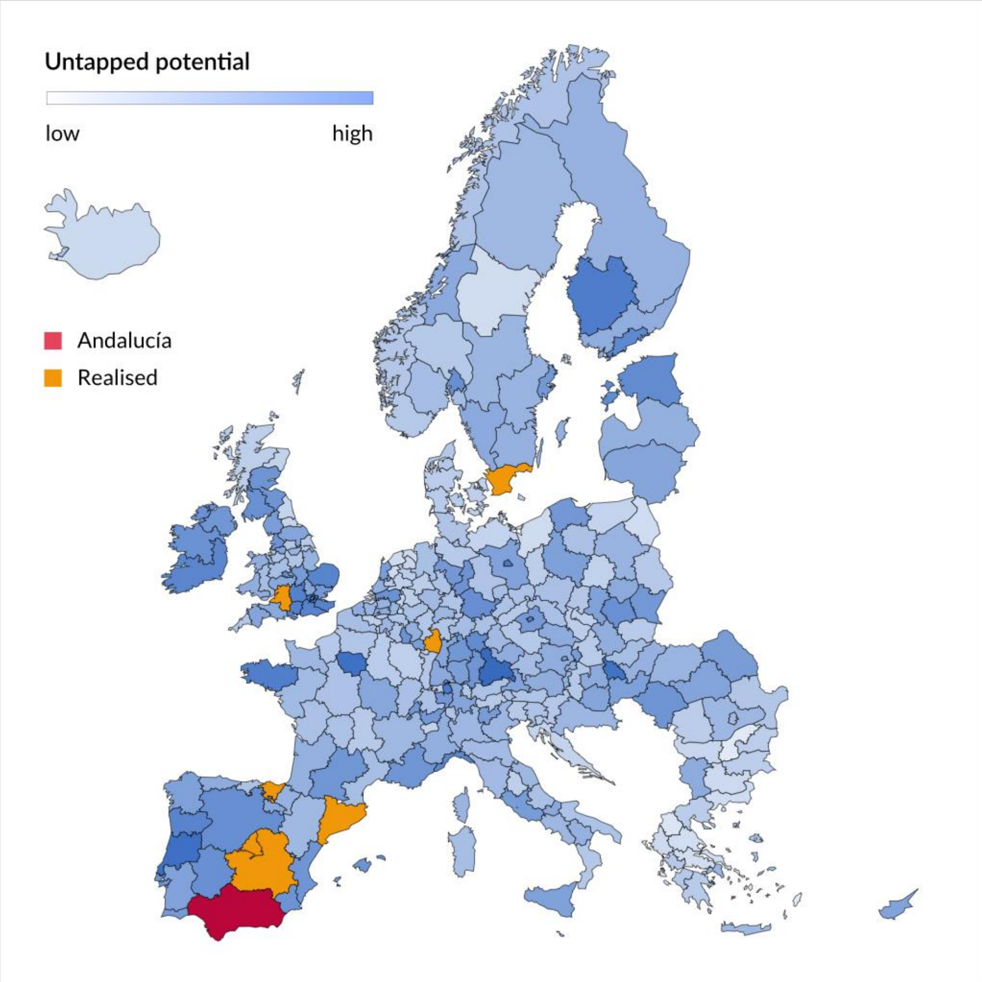
Figure 22: Untapped potential for inter-regional collaborations for Arnsberg (Germany) in hydrogen



Notes: This map shows the untapped potential score for inter-regional collaboration of Arnsberg (DEA5, coloured in red) with European regions in hydrogen technology. Appendix A.4 provides a detailed description of the methodology. Already realised inter-regional collaborations are coloured in orange. Source: OECD REGPAT, own calculation.

Figure 23 plots the untapped potential for inter-regional collaboration in virtual reality and augmented reality for Andalucía in Spain. The largest untapped potential is predicted for the more developed regions Oberbayern and Île-de-France, as well as the less developed region Centro in Portugal. Furthermore, a relatively high untapped potential score is found for collaboration with regions in Hungary and Germany as well as Portugal. The region already collaborates with the Spanish regions of Madrid and Castilla-La Mancha.

Figure 23: Untapped potential for inter-regional collaboration for Andalucía (Spain) in virtual and augmented reality



Notes: This map shows the untapped potential score for inter-regional collaboration of Andalucía (ES61, coloured in red) with European regions in virtual and augmented reality technology. Appendix A.4 provides a detailed description of the methodology. Already realised inter-regional collaborations are coloured in orange. Source: OECD REGPAT, own calculation.

5 Conclusions

It is a well-known fact that a region's capability to develop new technologies and innovation is a key driving force for its competitiveness and growth. This study shows that European regions differ widely in their capabilities to develop new green and digital technologies. This poses a potential threat to regional cohesion, as it may contribute to widening income disparities across Europe.

Overall, more developed EU regions are better equipped for developing technologies that digitize and green the economy: More than 80% of twin transition technologies are being developed in these economically leading regions today. Moreover, developed regions stand out in that their highest potential is concentrated in high-complex rather than low-complex green and digital technologies. This gives more developed regions a significant competitive advantage, as complex technologies are difficult to master and to imitate for other regions and therefore create higher economic returns. In contrast, the study finds that transition regions and less developed regions in Europe are responsible for only very modest shares of twin transition patents. What is more, their technological profiles also look very different to those of their more developed counterparts, as their highest potential for technological progress is found in green rather than digital technologies, and more often in low-complex rather than high-complex technologies. Those regions find it hard to develop twin transition technologies, as relevant capabilities are often missing: Local firms tend to lack absorptive capacity, the regional work force tends to have inadequate skills, and/or regional institutions tend to be weak.

Based on these findings on technological capabilities in European regions today, the prospects for economic cohesion do not look that bright. With their sets of technological capabilities, more developed regions are more likely to develop further twin transition technologies, thus pulling ahead from their less developed counterparts. Even if our analyses show that some transition and less developed regions have some potentials to develop twin transition technologies, especially green technologies, these are often not the most complex ones.

A promising route to greater European cohesion is to foster inter-regional collaboration: Instead of developing new technologies on their own, European regions should connect with other regions to access the technological capabilities they lack but are key to developing twin transition technologies. Our results show that more developed regions have many more inter-regional linkages than transition and less developed regions. However, on the whole, European regions are so far collaborating only to a limited extent, and they do so mainly within national borders and with regions that do not have the perfect set of complementary capabilities. This may be attributed to many factors: local firms may lack information on relevant capabilities and potential cooperation partners outside their own regions, especially in other countries. Much of the research infrastructure in Europe remains organized on a national scale, while research, innovation and green policies are often uncoordinated between European member states. Cultural differences between countries in Europe (in terms of language, norms and business practices) may also play a role. The untapped potential in collaborations between European regions when it comes to developing technologies for the twin transition seems huge.

While the study shows that more developed regions have on average the highest untapped potential in both digital and green technologies, transition regions and less developed regions do not trail that far behind. Matching these complementary technological capabilities across regional and national borders can lead to innovative technologies that can guide and promote the twin transition. If these inter-regional partnerships are geared to transition and less developed regions, economic cohesion in Europe could improve.

Our findings have important implications for European and regional policymaking: EU policymakers should focus on unlocking the unrealised potential of stronger inter-regional collaboration. We find numerous opportunities within the field of green and digital technology to match regions across the EU. By focusing on collaboration among and between transition regions and less developed regions, both technological progress and territorial cohesion can be improved at the same time. This will be particularly relevant when developing and refining the EU regions' Smart Specialisation strategies and when building inter-regional innovation partnerships in the context of the cohesion policy framework 2021-2027.

In order to tackle the widening gap that arises in the field of twin transition technologies in Europe, it is crucial to target more fully the opportunities we identified in low-income regions, and to remove bottlenecks that hamper the exploitation of these opportunities. This may be achieved by improving the regional educational and research infrastructure, for instance, and increasing the quality of the regional institutional governance.

At the regional level, policymakers in turn should refrain from developing strategies that support twin transition technologies for which their region has no relevant capabilities. Instead, they should develop policies that aim to exploit technological potential through the support of entrepreneurship, educational reforms, research capacity-building and quality of regional institutional governance. That way local opportunities are activated and obstacles are removed that prevent the shift in resources from local activities to those embracing twin transition technologies. This includes policy interventions with respect to laws and regulations that promote the mobility of entrepreneurs and workers from related activities, tackle weak university-industry linkages, and facilitate venture capital provision. Targeting technologies that are far removed from regional capabilities would imply a high-risk strategy that requires strong policy intervention.

Our results also suggest both regional and European policymakers stand to gain considerably from removing obstacles to cross-border cooperation in innovation, especially for less developed regions that have weaker local capabilities for developing twin transition technologies. In that context, European policy could help establish new cross-border research ventures that connect the right regions and partners. They could further help by attracting external firms such as multi-national enterprises (Neffke et al. 2018) and skilled migrants (Caviggioli et al. 2020) that can propel regions onto new growth paths.

This study has focused on how to foster the development of green and digital technologies across and between European regions. This development will play a major role in mastering the twin transition in Europe and in remaining competitive globally. However, there is increasing awareness that achieving the twin transition will not only rest on regions' technological capabilities. To unlock the full potential of green and digital technologies in Europe's regions, policymakers need to expand their focus on questions of implementation and diffusion (see Muench et al. 2022). This includes factors such as infrastructure, finance, human capital, regulations, and even social acceptance.

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Appendix

A.1 Classification of EU regions

For our analysis we consider 234 EU NUTS-2 regions (Ceuta (ES63) and Mayotte (FRY5) are excluded for lack of data) as well as 54 NUTS-2 regions in the United Kingdom (37), Switzerland (7), Norway (7), Iceland (2) and Liechtenstein (1). We use the 2013 version of the Nomenclature of Territorial Units for Statistics (NUTS).

We classify regions into less developed, transition and more developed regions based on the criteria applied in cohesion policy in the 2021-2027 programming period. This is why this classification is done for EU regions only. The corresponding thresholds of GDP per capita (in purchasing power standards) are set out in the Regulation (EU) 2021/1060 (common provisions) for the programming period 2021-2027:

- less developed regions: GDP per capita of less than 75% of EU average
- transition regions: GDP per capita between 75% and 100% of EU average
- more developed regions: above-average GDP per capita.

Five EU regions (Lithuania, the two Irish regions as well as one Hungarian and one Polish region) have been split in the 2016 NUTS version and are therefore not directly classified by the Regulation. Those regions are classified based on the rule set out in the Regulation (EU) 2021/1060 meaning that they are considered not split up for this study.

Table A.1: List of EU regions and their classification based on their level of economic development

Code	Name	Category	Code	Name	Category
AT11	Burgenland (AT)	Transition	FR22	Picardie	Transition
AT12	Niederösterreich	More	FR23	Haute-Normandie	Transition
AT13	Wien	More	FR24	Centre	Transition
AT21	Kärnten	More	FR25	Basse-Normandie	Transition
AT22	Steiermark	More	FR26	Bourgogne	Transition
AT31	Oberösterreich	More	FR30	Nord - Pas-de-Calais	Transition
AT32	Salzburg	More	FR41	Lorraine	Transition
AT33	Tirol	More	FR42	Alsace	Transition
AT34	Vorarlberg	More	FR43	Franche-Comté	Transition
BE10	Région de Bruxelles-Capitale	More	FR51	Pays de la Loire	Transition
BE21	Prov. Antwerpen	More	FR52	Bretagne	Transition
BE22	Prov. Limburg (BE)	Transition	FR53	Poitou-Charentes	Transition
BE23	Prov. Oost-Vlaanderen	More	FR61	Aquitaine	Transition
BE24	Prov. Vlaams-Brabant	More	FR62	Midi-Pyrénées	Transition
BE25	Prov. West-Vlaanderen	More	FR63	Limousin	Transition
BE31	Prov. Brabant Wallon	More	FR71	Rhône-Alpes	More
BE32	Prov. Hainaut	Transition	FR72	Auvergne	Transition
BE33	Prov. Liège	Transition	FR81	Languedoc-Roussillon	Transition
BE34	Prov. Luxembourg (BE)	Less	FR82	Provence-Alpes-Côte d'Azur	Transition
BE35	Prov. Namur	Transition	FR83	Corse	Transition
BG31	Severozapaden	Less	FRY1	Guadeloupe	Less
BG32	Severen tsentralen	Less	FRY2	Martinique	Transition
BG33	Severoiztochen	Less	FRY3	Guyane	Less
BG34	Yugoiztochen	Less	FRY4	Réunion	Less

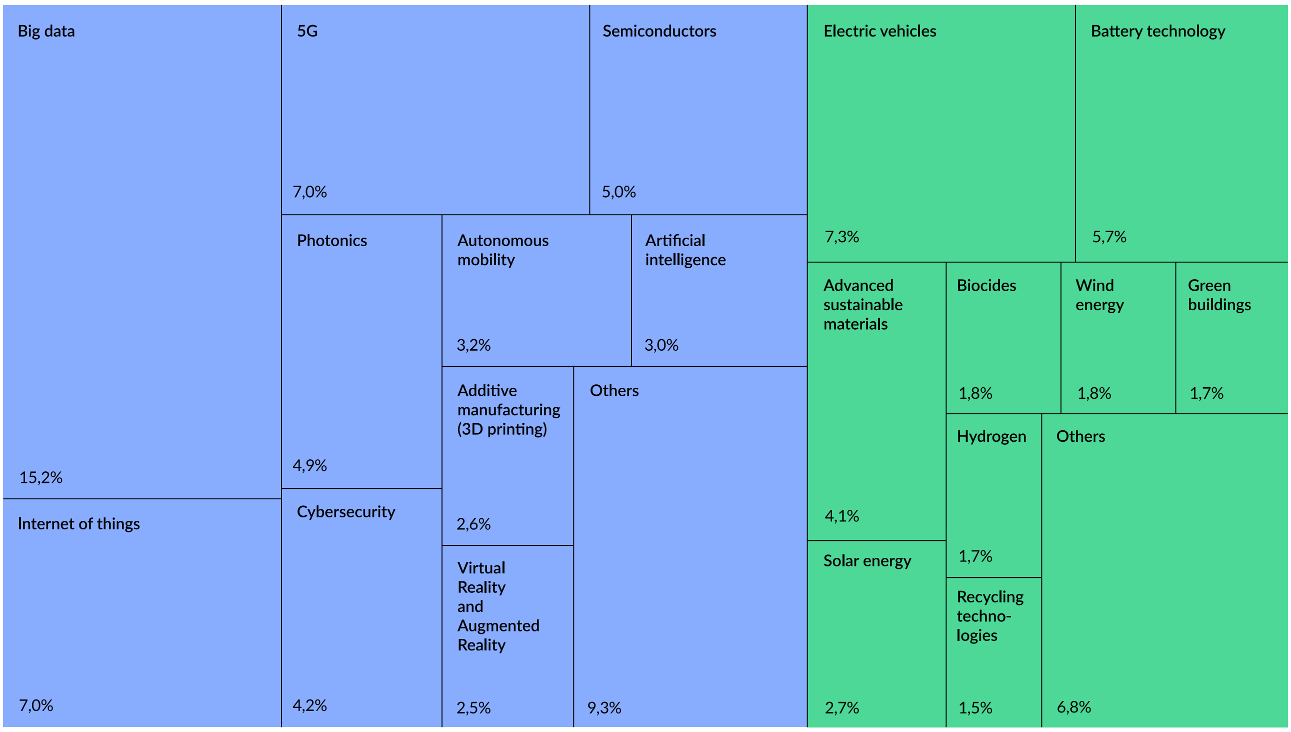
Code	Name	Category	Code	Name	Category
BG41	Yugozapaden	Transition	HR03	Jadranska Hrvatska	Less
BG42	Yuzhen tsentralen	Less	HR04	Kontinentalna Hrvatska	Less
CY00	Kypros	Transition	HU10	Közép-Magyarország	More
CZ01	Praha	More	HU21	Közép-Dunántúl	Less
CZ02	Strední Cechy	Transition	HU22	Nyugat-Dunántúl	Less
CZ03	Jihozápad	Transition	HU23	Dél-Dunántúl	Less
CZ04	Severozápad	Less	HU31	Észak-Magyarország	Less
CZ05	Severovýchod	Less	HU32	Észak-Alföld	Less
CZ06	Jihovýchod	Transition	HU33	Dél-Alföld	Less
CZ07	Strední Morava	Less	IE01	Border, Midland and Western	Transition
CZ08	Moravskoslezsko	Less	IE02	Southern and Eastern	More
DE11	Stuttgart	More	ITC1	Piemonte	More
DE12	Karlsruhe	More	ITC2	Valle d’Aosta/Vallée d’Aoste	More
DE13	Freiburg	More	ITC3	Liguria	More
DE14	Tübingen	More	ITC4	Lombardia	More
DE21	Oberbayern	More	ITF1	Abruzzo	Transition
DE22	Niederbayern	More	ITF2	Molise	Less
DE23	Oberpfalz	More	ITF3	Campania	Less
DE24	Oberfranken	More	ITF4	Puglia	Less
DE25	Mittelfranken	More	ITF5	Basilicata	Less
DE26	Unterfranken	More	ITF6	Calabria	Less
DE27	Schwaben	More	ITG1	Sicilia	Less
DE30	Berlin	More	ITG2	Sardegna	Less
DE40	Brandenburg	Transition	ITH1	Provincia 49utónoma di Bolzano/Bozen	More
DE50	Bremen	More	ITH2	Provincia Autonoma di Trento	More
DE60	Hamburg	More	ITH3	Veneto	More
DE71	Darmstadt	More	ITH4	Friuli-Venezia Giulia	More
DE72	Gießen	More	ITH5	Emilia-Romagna	More
DE73	Kassel	More	ITI1	Toscana	More
DE80	Mecklenburg-Vorpommern	Transition	ITI2	Umbria	Transition
DE91	Braunschweig	More	ITI3	Marche	Transition
DE92	Hannover	More	ITI4	Lazio	More
DE93	Lüneburg	Transition	LT00	Lietuva	Transition
DE94	Weser-Ems	More	LU00	Luxembourg	More
DEA1	Düsseldorf	More	LV00	Latvija	Less
DEA2	Köln	More	MT00	Malta	Transition
DEA3	Münster	More	NL11	Groningen	More
DEA4	Detmold	More	NL12	Friesland (NL)	Transition
DEA5	Arnsberg	More	NL13	Drenthe	Transition
DEB1	Koblenz	More	NL21	Overijssel	More
DEB2	Trier	Transition	NL22	Gelderland	More
DEB3	Rheinhessen-Pfalz	More	NL23	Flevoland	Transition
DEC0	Saarland	More	NL31	Utrecht	More
DED2	Dresden	Transition	NL32	Noord-Holland	More
DED4	Chemnitz	Transition	NL33	Zuid-Holland	More
DED5	Leipzig	More	NL34	Zeeland	More
DEE0	Sachsen-Anhalt	Transition	NL41	Noord-Brabant	More
DEF0	Schleswig-Holstein	More	NL42	Limburg (NL)	More
DEG0	Thüringen	Transition	PL11	Łódzkie	Less
DK01	Hovedstaden	More	PL12	Mazowieckie	More
DK02	Sjælland	Transition	PL21	Małopolskie	Less
DK03	Syddanmark	More	PL22	Śląskie	Less
DK04	Midtjylland	More	PL31	Lubelskie	Less
DK05	Nordjylland	More	PL32	Podkarpackie	Less
EE00	Eesti	Transition	PL33	Świętokrzyskie	Less
EL30	Attiki	Transition	PL34	Podlaskie	Less
EL41	Voreio Aigaio	Less	PL41	Wielkopolskie	Transition
EL42	Notio Aigaio	Transition	PL42	Zachodniopomorskie	Less
EL43	Kriti	Less	PL43	Lubuskie	Less
EL51	Anatoliki Makedonia. Thraki	Less	PL51	Dolnośląskie	Transition

Code	Name	Category	Code	Name	Category
EL52	Kentriki Makedonia	Less	PL52	Opolskie	Less
EL53	Dytiki Makedonia	Less	PL61	Kujawsko-Pomorskie	Less
EL54	Thessalia	Less	PL62	Warmińsko-Mazurskie	Less
EL61	Ipeiros	Less	PL63	Pomorskie	Less
EL62	Ionia Nisia	Less	PT11	Norte	Less
EL63	Dytiki Ellada	Less	PT15	Algarve	Transition
EL64	Sterea Ellada	Less	PT16	Centro (PT)	Less
EL65	Peloponnisos	Less	PT17	Lisboa	More
ES11	Galicia	Transition	PT18	Alentejo	Less
ES12	Principado de Asturias	Transition	PT20	Região Autónoma dos Açores	Less
ES13	Cantabria	Transition	PT30	Região Autónoma da Madeira	Less
ES21	País Vasco	More	RO11	Nord-Vest	Less
ES22	Comunidad Foral de Navarra	More	RO12	Centru	Less
ES23	La Rioja	Transition	RO21	Nord-Est	Less
ES24	Aragón	More	RO22	Sud-Est	Less
ES30	Comunidad de Madrid	More	RO31	Sud – Muntenia	Less
ES41	Castilla y León	Transition	RO32	Bucureşti-Ilfov	More
ES42	Castilla-La Mancha	Less	RO41	Sud-Vest Oltenia	Less
ES43	Extremadura	Less	RO42	Vest	Less
ES51	Cataluña	More	SE11	Stockholm	More
ES52	Comunidad Valenciana	Transition	SE12	Östra Mellansverige	More
ES53	Illes Balears	Transition	SE21	Småland med öarna	More
ES61	Andalucía	Less	SE22	Sydsverige	More
ES62	Región de Murcia	Transition	SE23	Västsverige	More
ES64	Ciudad Autónoma de Melilla	Less	SE31	Norra Mellansverige	Transition
ES70	Canarias	Transition	SE32	Mellersta Norrland	More
FI19	Länsi-Suomi	Transition	SE33	Övre Norrland	More
FI1B	Helsinki-Uusimaa	More	SI03	Zahodna Slovenija	Less
FI1C	Etelä¤-Suomi	Transition	SI04	Vzhodna Slovenija	More
FI1D	Pohjois- ja Itä¤-Suomi	Transition	SK01	Bratislavský kraj	More
FI20	Åland	More	SK02	Západné Slovensko	Less
FR10	Île-de-France	More	SK03	Stredné Slovensko	Less
FR21	Champagne-Ardenne	Transition	SK04	Východné Slovensko	Less

Notes: This table lists the classification of EU NUTS-2 regions based on their level of economic development following Regulation (EU) 2021/1060 (common provisions). Source: European Commission (2022h).

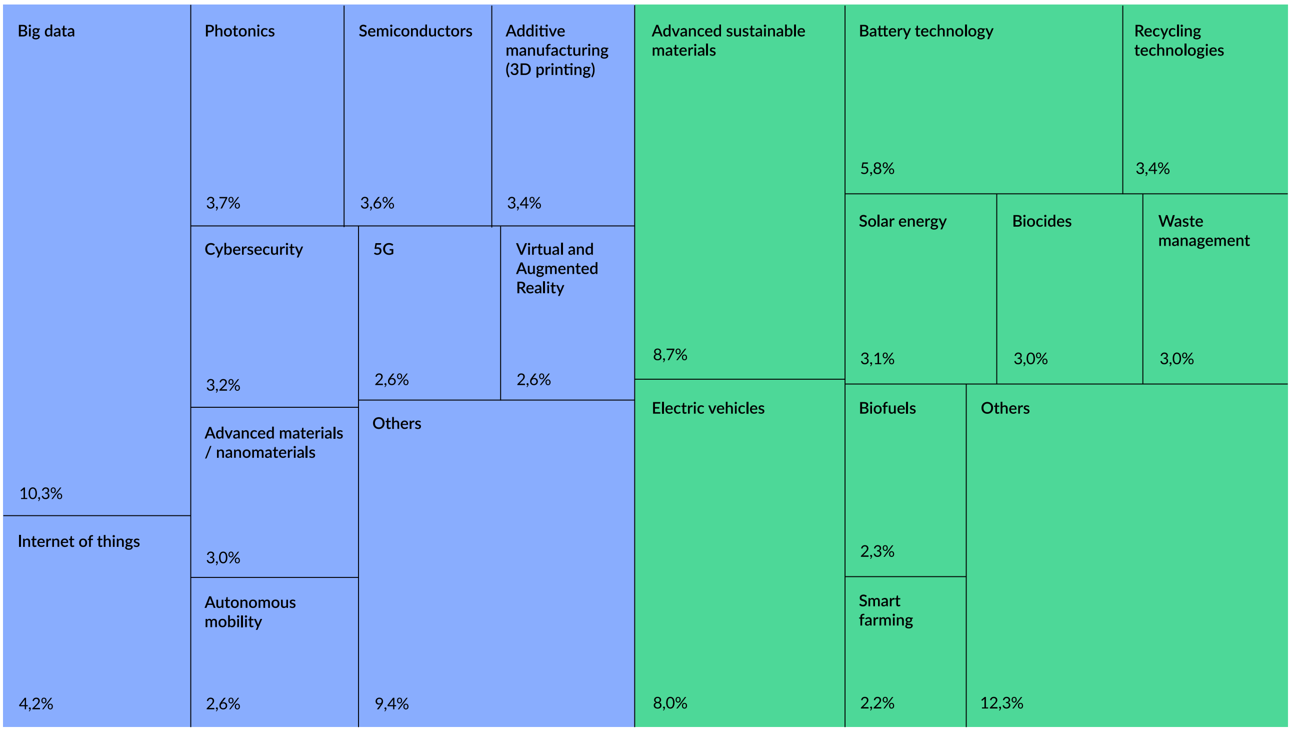
A.2 Patent output in twin transition technologies in different group of regions

Figure A.1. Twin transition technological structure in more developed regions



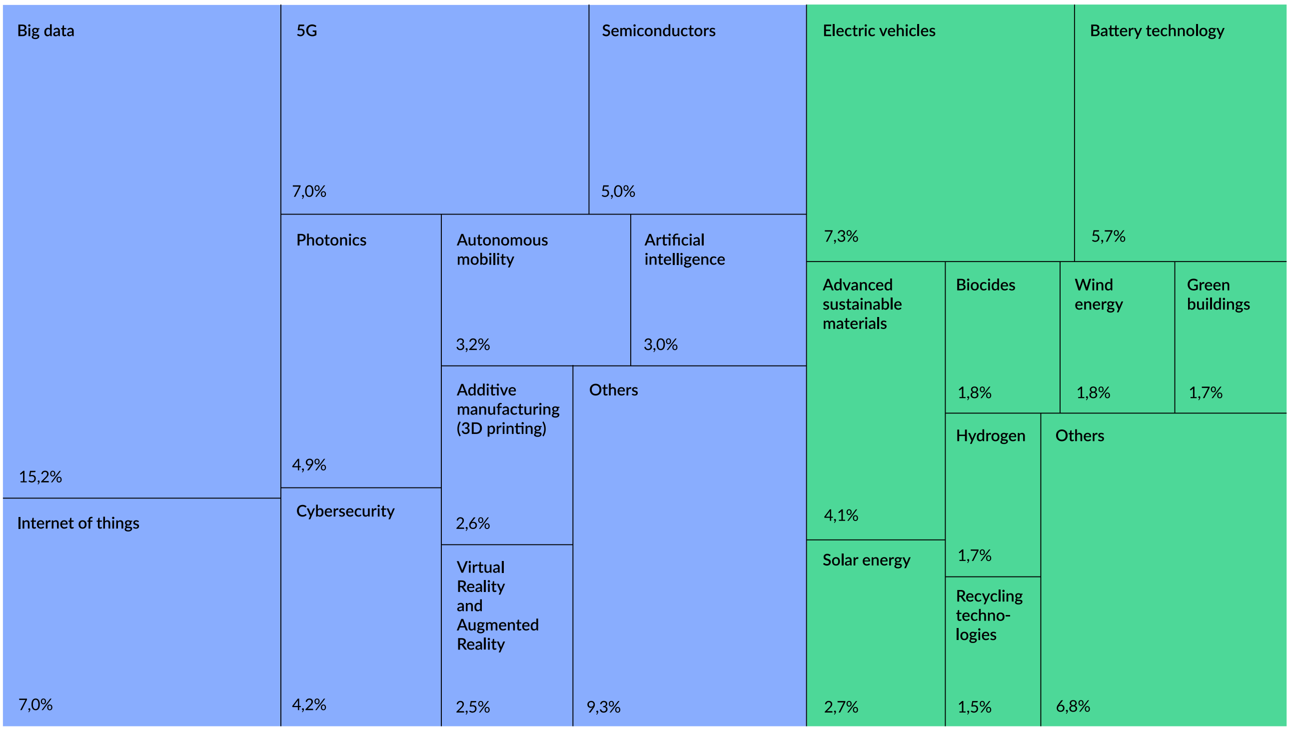
Notes: This map shows the distribution of patents in more developed regions. Digital technologies are coloured in blue, green technologies in green. Source: OECD REGPAT, own elaboration.

Figure A.2: Twin transition technological structure in transition regions



Notes: This map shows the distribution of patents in transition regions. Digital technologies are coloured in blue, green technologies in green. Source: OECD REGPAT, own elaboration.

Figure A.3: Twin transition technological structure in less developed regions



Notes: This map shows the distribution of patents in less developed regions. Digital technologies are coloured in blue, green technologies in green. Source: OECD REGPAT, own elaboration.

A.3 Complexity of green and digital technologies

Complexity makes knowledge hard to codify and difficult to imitate copy (Kogut and Zander 1993). Increasing an economy's complexity is beneficial for economic development (Hidalgo and Hausmann 2009; Davies and Maré 2019; Mewes and Broekel 2020). Despite this incentive to develop complex activities, regions often fail to do so (Balland et al. 2019). Only a few places can master complex knowledge because they have available a wide range of capabilities that need to be combined to develop complex activities (Balland and Rigby 2017). We apply this concept topic of complexity to the twin transition. We follow Hidalgo and Hausmann (2009) in determining the complexity of technologies. Their complexity measure reflects the difficulty of mastering the capabilities that are required to excel a domain illustrated by its rarity on the one hand, and the diversity of capabilities that need to be combined on the other hand. Complexity is measured by using the eigenvector reformulation of the method of reflection (Balland and Rigby 2017). The starting point is a binary-valued network that connects regions to technologies in which they have a relative comparative advantage. This matrix M has dimension n = 288 regions (NUTS-2 regions in Europe) by k = 42 technologies. This matrix M is row standardized along with its transpose. The resulting technology matrix is a square matrix with dimension equal to the number of technologies. The complexity of each technology is given by the elements of the second eigenvector of the matrix.

In Table A.2, we list the level of complexity for all twin transition technologies. What can be observed is that digital technologies are far more complex than green technologies. Battery technology is the most complex green technology but does not even rank in among the Top 10 most complex digital technologies. The most complex twin transition technologies turn out to be big data, internet of things, virtual and augmented reality, artificial intelligence (AI), and cybersecurity. Most green technologies are not exhibiting high levels of complexity. The most complex ones are battery technology, solar energy, smart farming, biocides and electric vehicles (EVs).

Table A.2: Complexity levels of twin transition technologies

Digital technologies	Complexity	Green technologies	Complexity
Big data	97.1	Battery technology	49.0
Internet of things	85.5	Solar (thermal) energy	45.3
Virtual and augmented reality	76.1	Smart farming	44.4
Artificial intelligence	75.7	Biocides	44.3
Cybersecurity (privacy-enhancing technologies)	73.0	Electric vehicles	42.8
Cryptography, distributed ledger technology	69.0	Wind energy	41.1
Cloud and edge computing	68.8	Advanced sustainable materials (composite)	39.6
5G	68.5	Recycling	38.8
Photonics	55.7	Green construction/buildings	37.5
Autonomous mobility	55.4	Waste management	36.7
Semiconductors	50.0	Biofuels	35.8
Advanced materials/nanomaterials	47.8	Hydrogen fuels	34.1
High performance computing/quantum computers	46.4	Marine energy	33.4
Drones	40.5	Nuclear energy	32.9
Smart grids	38.8	Fuels from waste	32.5
Additive manufacturing (3D printing)	34.5	Bio fertilizers	31.5
Robotics	32.7	Water treatment	30.8
Broadband	28.3	HVAC systems	29.1
		Hydropower	28.7
		Energy conservation technologies	25.5
		Carbon (GHG) capturing technology	25.1
		Sustainable packaging	22.4
		Geothermal energy	20.9
		Heating pumps	20.7

Source: OECD REGPAT, own elaboration.

A.4 Computing untapped potential of linkages in innovation between European regions

Untapped potential linkages refer to inter-regional connections that have not yet been realised but hold the promise of unlocking twin transition diversification and innovation opportunities for EU regions and of scaling complex technologies at the EU level. There is no consensus on how to compute these untapped potential linkages. Our proposed approach should be more understood as a way to think about going beyond the current EU innovation system by putting more emphasis on potential complementarity, reducing the impact of border effects, while being realistic in terms of existing frictions and constraints.

Our method consists of three steps:

1. We estimate a gravity model to evaluate the forces that shape inter-regional collaborations.
2. We use the coefficients derived from step 1 to predict the number of linkages between two regions but we remove the same-country effect and add a complementarity effect instead.
3. We subtract the number of actual linkages from the predicted number of linkages. A large score indicates a large untapped potential. Below we describe these steps in more detail.

In the first step, we estimate an OLS extended gravity model to explain the number of interregional linkages (in logs) between regions *i* and *j* for technology *k* of the following form:

$$\log(\text{linkages})_{i,j,k} = \beta_0 + \beta_1 \log(\text{distance})_{i,j} + \beta_2 \log(\text{mass})_{i,j} + \beta_3 \text{country}_{i,j} + \beta_4 \text{reldens}_{i,j,k} + \beta_5 \text{reldensdist}_{i,j,k}$$

Explanatory variables are *distance* (distance between regions *i* and *j*, measured in kilometers) and *mass* (number of patents in regions *i* and *j*). Further, we account with a dummy variable *country* for same-country-effects (value 1 if region *i* and *j* are located in the same country, 0 otherwise). To measure the complementarity of technological capabilities between region *i* and *j*, we include in our model *reldens* (relatedness density, defined at the regional pair level, see above) and *reldensdist* (absolute distance in related density levels between two regions).

The results are reported in Table A.3. In the first specification, we regress the number of inter-regional linkages on spatial distance and on the sum of patents of the two regions (mass). We find a negative effect for distance with a 0.19% decrease in collaboration for every 1% increase in distance as shown in column (1). This elasticity of knowledge flows with respect to distance is well-known in the literature (Broekel et al. 2014) and is a real friction when building a pan-European innovation system. Mechanically, patent mass has a positive effect, implying that regions that are active in patenting are more likely to collaborate. In the second specification, we add the impact of inventors being in the same country (see column (2)). We find a strong effect: When controlling for this variable the elasticity of knowledge flows to distance goes down to 0.09%. In the third specification (column (3)), we add relatedness density to the equation and find that region pairs that have related capabilities to a given technology *k* are more likely to collaborate. Finally, we add in the fourth specification (column (4)) the distance in relatedness density between two regions and find that the capability gaps between regions negatively impact collaborations. Specification five (column (5)) is similar to specification four but uses centered and standardized variables to increase comparability of coefficients to compare the impact of one standard deviation. Being in the same country has the strongest effect, more than twice as strong as patent mass and almost three times as strong as distance. Relatedness density and distance have a comparable impact in terms of magnitude.

In the second step, we use the coefficients of our benchmark specification five to predict the number of linkages between two regions in a specific technology. For the prediction, we tweak the model to create an ideal EU inter-regional technology network by substituting the impact of the same country variable by the impact of complementarity. This means that we create an ideal world where we replace the influence of political boundaries with the influence of regions' combinatorial potential. Technically, we remove the same-country effect and add a complementarity effect instead (using the same-country coefficient). We rescale both realised and predicted (ideal) linkages from 0 to 100.

In the third step, we subtract the (rescaled) number of realised linkages from the (rescaled) predicted number of linkages. A large score indicates a large untapped potential.

Table A.3: Estimation results of the extended gravity model

	Dependent variable: inter-regional connections (log)				
	(1)	(2)	(3)	(4)	(5)
Distance (log)	-0.190***	-0.090***	-0.085***	-0.084***	-0.065***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Mass (log)	0.020***	0.022***	0.019***	0.019***	0.077***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0005)
Same country		0.742***	0.746***	0.746***	0.182***
		(0.002)	(0.002)	(0.002)	(0.0005)
Relatedness Density			0.002***	0.002***	0.053***
			(0.00002)	(0.00002)	(0.0005)
Distance in RelDens				-0.001***	-0.012***
				(0.00003)	(0.0005)
Constant	-5.481***	-6.230***	-6.369***	-6.374***	-6.805***
	(0.004)	(0.005)	(0.005)	(0.005)	(0.0004)
Observations	3,471,552	3,471,552	3,471,552	3,471,552	3,471,552
R^2	0.042	0.077	0.080	0.080	0.080

Notes: This table lists the results of OLS regressions. Significance levels: * p-value < 0.05; ** p-value < 0.01; *** p-value < 0.001.

A.5 Highest untapped potential for inter-regional linkages between regions

Table A.4: Top 3 EU region pairs with the highest average untapped potential for inter-regional collaboration in twin transition technologies

#	NUTS-2 Region	Partner region	Technologies
MORE DEVELOPED REGIONS – MORE DEVELOPED REGIONS			
1	ITH4 Friuli-Venezia Giulia	DE21 Oberbayern	Digital
2	ITC2 Valle d'Aosta	ITC4 Lombardia	Green
3	ITC2 Valle d'Aosta	FR71 Rhône-Alpes	Green
MORE DEVELOPED REGIONS – TRANSITION REGIONS			
1	ITC2 Valle d'Aosta	FR82 Provence-Alpes-Côte d'Azur	Digital
2	DE11 Stuttgart	FR82 Provence-Alpes-Côte d'Azur	Digital
3	DEA2 Köln	NL12 Friesland (NL)	Green
MORE DEVELOPED REGIONS – LESS DEVELOPED REGIONS			
1	SE21 Småland och öarna	PL63 Pomorskie	Digital
2	AT12 Niederösterreich	PL21 Małopolskie	Digital
3	DE71 Darmstadt	PL63 Pomorskie	Digital
TRANSITION REGIONS – MORE DEVELOPED REGIONS			
1	CZ03 Jihozápad	DE21 Oberbayern	Digital
2	NL23 Flevoland	DE21 Oberbayern	Digital
3	FR83 Corse	ITC4 Lombardia	Green
TRANSITION REGIONS – TRANSITION REGIONS			
1	FR83 Corse	FR82 Provence-Alpes-Côte d'Azur	Digital
2	DEG0 Thüringen	DE80 Mecklenburg-Vorpommern	Green
3	DED2 Dresden	CZ02 Střední Čechy	Digital
TRANSITION REGIONS – LESS DEVELOPED REGIONS			
1	PL51 Dolnośląskie	PL21 Małopolskie	Digital
2	DED2 Dresden	PL21 Małopolskie	Digital
3	DE93 Lüneburg	PL63 Pomorskie	Digital
LESS DEVELOPED REGIONS – MORE DEVELOPED REGIONS			
1	CZ04 Severozápad	DE21 Oberbayern	Digital
2	SI03 Vzhodna Slovenija	DE21 Oberbayern	Digital
3	SK02 Západné Slovensko	DE21 Oberbayern	Digital
LESS DEVELOPED REGIONS – TRANSITION REGIONS			
1	CZ04 Severozápad	DE40 Brandenburg	Digital
2	CZ04 Severozápad	DED4 Chemnitz	Green
3	PL42 Zachodniopomorskie	DEE0 Sachsen-Anhalt	Green
LESS DEVELOPED REGIONS – LESS DEVELOPED REGIONS			
1	SK04 Východné Slovensko	PL21 Małopolskie	Digital
2	CZ08 Moravskoslezsko	PL21 Małopolskie	Digital
3	ES43 Extremadura	PT16 Centro	Digital

Notes: This table lists the Top 3 region pairs with the highest untapped potential for more developed, transition and less developed regions each in terms of the regional average untapped potential score across digital or green technologies and partner regions in the respective NUTS-2 region.

A.6 Region-specific results

Table A.5: Overview of regional activities in developing twin transition technologies

NUTS-2		Digital technologies		Green technologies	
Code	Name	Patents	RCA	Patents	RCA
AT11	Burgenland (AT)	21	0.64	53	1.42
AT12	Niederösterreich	404	0.74	404	1.31
AT13	Wien	597	0.92	270	0.86
AT21	Kärnten	152	1.12	74	0.85
AT22	Steiermark	527	0.76	534	1.07
AT31	Oberösterreich	434	0.65	653	1.00
AT32	Salzburg	66	0.45	89	0.93
AT33	Tirol	111	0.56	126	1.05
AT34	Vorarlberg	220	0.49	198	0.73
BE10	Région de Bruxelles-Capitale / Brussels Hoofdstedelijk Gewest	492	1.00	311	0.93
BE21	Prov. Antwerpen	558	0.70	357	0.86
BE22	Prov. Limburg (BE)	142	0.74	128	1.09
BE23	Prov. Oost-Vlaanderen	351	0.60	384	1.09
BE24	Prov. Vlaams-Brabant	716	0.94	376	0.81
BE25	Prov. West-Vlaanderen	147	0.97	156	0.94
BE31	Prov. Brabant Wallon	163	0.62	167	0.81
BE32	Prov. Hainaut	129	0.71	137	0.99
BE33	Prov. Liège	168	1.21	183	1.41
BE34	Prov. Luxembourg (BE)	46	0.94	32	1.03
BE35	Prov. Namur	82	0.86	83	1.22
BG31	Severozapaden	1	0.16	8	8.02
BG32	Severen tsentralen	0	0.00	10	4.83
BG33	Severoiztochen	9	1.02	7	5.23
BG34	Yugoiztochen	8	0.73	2	0.28
BG41	Yugozapaden	57	0.79	63	2.71
BG42	Yuzhen tsentralen	5	0.72	9	1.10
CH01	Région lémanique	1433	0.98	466	0.66
CH02	Espace Mittelland	562	0.59	427	0.75
CH03	Nordwestschweiz	779	0.57	817	0.86
CH04	Zürich	1668	1.09	758	0.83
CH05	Ostschweiz	361	0.55	306	0.65
CH06	Zentralschweiz	491	0.88	258	0.90
CH07	Ticino	141	0.81	121	1.54
CY00	Kýpros	29	0.76	15	0.98
CZ01	Praha	180	1.13	69	1.12
CZ02	Střední Čechy	134	1.02	58	0.95
CZ03	Jihozápad	24	0.56	38	2.31
CZ04	Severozápad	21	0.62	18	1.46
CZ05	Severovýchod	63	0.66	52	0.91
CZ06	Jihovýchod	60	0.75	59	1.30
CZ07	Střední Morava	41	0.58	51	1.28
CZ08	Moravskoslezsko	22	0.45	27	1.66
DE11	Stuttgart	3927	0.90	3598	0.90
DE12	Karlsruhe	2219	0.91	1730	0.80
DE13	Freiburg	866	0.61	807	0.70
DE14	Tübingen	1289	0.68	1036	0.74
DE21	Oberbayern	9292	1.44	3619	0.76
DE22	Niederbayern	844	1.11	571	0.87
DE23	Oberpfalz	2295	1.71	900	0.80
DE24	Oberfranken	499	0.68	658	1.35
DE25	Mittelfranken	2286	1.09	1481	1.27
DE26	Unterfranken	612	0.63	715	1.00
DE27	Schwaben	1003	1.17	685	0.70
DE30	Berlin	2121	1.22	739	0.58
DE40	Brandenburg	662	1.02	268	0.69
DE50	Bremen	144	0.94	164	1.07
DE60	Hamburg	392	0.69	413	0.81
DE71	Darmstadt	2751	1.05	1283	0.77
DE72	Gießen	201	0.54	209	0.97
DE73	Kassel	229	1.04	283	1.17
DE80	Mecklenburg-Vorpommern	80	0.68	127	1.47
DE91	Braunschweig	883	0.90	688	0.94
DE92	Hannover	784	0.76	517	0.58
DE93	Lüneburg	170	0.55	267	1.13

NUTS-2		Digital technologies		Green technologies	
Code	Name	Patents	RCA	Patents	RCA
DE94	Weser-Ems	273	0.55	614	1.72
DEA1	Düsseldorf	1114	0.47	1697	0.89
DEA2	Köln	2105	0.73	1728	0.88
DEA3	Münster	368	0.51	667	1.17
DEA4	Detmold	596	0.67	497	0.73
DEA5	Arnsberg	683	0.58	941	1.03
DEB1	Koblenz	92	0.30	205	0.83
DEB2	Trier	60	0.55	58	0.55
DEB3	Rheinhessen-Pfalz	921	0.54	1209	1.20
DEC0	Saarland	154	0.70	122	0.95
DED2	Dresden	698	1.14	411	0.98
DED4	Chemnitz	245	1.00	198	1.30
DED5	Leipzig	176	0.97	103	0.99
DEE0	Sachsen-Anhalt	257	0.72	249	1.43
DEF0	Schleswig-Holstein	315	0.55	427	1.01
DEG0	Thüringen	457	0.89	277	0.84
DK01	Hovedstaden	617	0.50	782	1.27
DK02	Sjælland	110	0.55	195	1.84
DK03	Syddanmark	252	0.74	563	1.83
DK04	Midtjylland	405	0.68	1239	2.33
DK05	Nordjylland	575	1.09	286	1.17
EE00	Eesti	134	1.64	52	1.42
EL30	Attiki	278	1.24	61	0.60
EL41	Voreio Aigaio	7	2.24	2	1.14
EL42	Notio Aigaio	0	0.00	1	2.78
EL43	Kriti	6	0.40	13	2.48
EL51	Anatoliki Makedonia, Thraki	1	0.08	4	1.31
EL52	Kentriki Makedonia	28	0.60	25	1.31
EL53	Dytiki Makedonia	2	3.82	1	0.69
EL54	Thessalia	5	1.11	1	0.07
EL61	Ipeiros	1	0.34	1	0.13
EL62	Ionia Nisia	0	0.00	0	0.00
EL63	Dytiki Ellada	27	1.18	16	3.41
EL64	Sterea Ellada	2	0.70	3	0.80
EL65	Peloponnisos	5	0.89	3	0.52
ES11	Galicia	60	0.97	43	0.88
ES12	Principado de Asturias	43	1.12	37	1.95
ES13	Cantabria	8	0.22	16	1.90
ES21	País Vasco	135	0.83	135	1.37
ES22	Comunidad Foral de Navarra	55	0.83	98	2.08
ES23	La Rioja	16	0.56	12	0.45
ES24	Aragón	62	0.50	107	2.48
ES30	Comunidad de Madrid	1257	1.42	371	1.02
ES41	Castilla y León	44	0.67	62	2.37
ES42	Castilla-La Mancha	36	1.18	36	1.56
ES43	Extremadura	3	0.46	4	0.29
ES51	Cataluña	1285	1.15	364	0.54
ES52	Comunidad Valenciana	244	0.72	262	1.65
ES53	Illes Balears	36	1.03	11	1.50
ES61	Andalucía	203	0.78	202	2.05
ES62	Región de Murcia	37	0.58	73	3.14
ES64	Ciudad Autónoma de Melilla	0	0.00	0	0.00
ES70	Canarias	38	1.14	34	1.80
FI19	Länsi-Suomi	913	1.46	323	1.07
FI1B	Helsinki-Uusimaa	3943	1.43	771	1.05
FI1C	Etelä-Suomi	476	2.60	337	1.62
FI1D	Pohjois- ja Itä-Suomi	1354	1.26	212	0.89
FI20	Åland	6	0.75	6	7.11
FR10	Île-de-France	6701	0.98	3884	1.00
FR21	Champagne-Ardenne	59	0.61	106	2.14
FR22	Picardie	117	0.37	303	0.76
FR23	Haute-Normandie	101	0.31	238	0.84
FR24	Centre	209	0.56	299	0.95
FR25	Basse-Normandie	133	0.79	77	1.26
FR26	Bourgogne	85	0.63	69	1.00
FR30	Nord - Pas-de-Calais	203	0.90	228	1.12
FR41	Lorraine	145	0.45	230	1.22
FR42	Alsace	262	0.56	305	0.66
FR43	Franche-Comté	71	0.37	168	1.22
FR51	Pays de la Loire	246	0.55	344	1.36
FR52	Bretagne	1217	1.32	298	0.88

NUTS-2		Digital technologies		Green technologies	
Code	Name	Patents	RCA	Patents	RCA
FR53	Poitou-Charentes	59	0.62	146	1.62
FR61	Aquitaine	368	0.76	365	1.30
FR62	Midi-Pyrénées	767	1.00	445	1.23
FR63	Limousin	28	0.42	29	1.17
FR71	Rhône-Alpes	2431	0.99	1926	1.48
FR72	Auvergne	182	0.44	170	0.46
FR81	Languedoc-Roussillon	221	0.69	251	2.14
FR82	Provence-Alpes-Côte d'Azur	1203	1.08	401	1.23
FR83	Corse	6	0.69	1	0.15
FRY1	Guadeloupe	5	0.82	2	0.60
FRY2	Martinique	8	1.71	0	0.00
FRY3	Guyane	0	0.00	3	2.13
FRY4	Réunion	16	1.26	14	1.21
HR03	Jadranska Hrvatska	2	0.17	11	1.68
HR04	Kontinentalna Hrvatska	35	0.99	20	1.14
HU10	Közép-Magyarország	744	1.44	165	0.79
HU21	Közép-Dunántúl	58	0.68	37	0.90
HU22	Nyugat-Dunántúl	51	1.29	33	1.18
HU23	Dél-Dunántúl	22	0.88	6	0.93
HU31	Észak-Magyarország	23	0.66	10	0.34
HU32	Észak-Alföld	30	0.83	32	3.92
HU33	Dél-Alföld	143	2.17	27	0.94
IE01	Border, Midland and Western	213	0.84	62	1.11
IE02	Southern and Eastern	1104	2.17	231	0.99
IS01	Höfuðborgarsvæði	25	1.20	32	1.89
IS02	Landsbyggð	6	0.26	21	3.26
ITC1	Piemonte	463	0.68	478	1.24
ITC2	Valle d'Aosta/Vallée d'Aoste	8	0.49	33	1.14
ITC3	Liguria	248	1.57	115	1.97
ITC4	Lombardia	945	0.63	1033	1.28
ITF1	Abruzzo	74	0.55	112	1.92
ITF2	Molise	6	0.64	13	1.16
ITF3	Campania	196	0.79	98	0.88
ITF4	Puglia	83	0.71	92	1.95
ITF5	Basilicata	11	0.52	9	0.78
ITF6	Calabria	12	0.26	36	2.76
ITG1	Sicilia	295	1.80	50	1.07
ITG2	Sardegna	16	0.60	32	2.07
ITH1	Provincia Autonoma di Bolzano/Bozen	29	0.50	44	2.03
ITH2	Provincia Autonoma di Trento	81	0.92	72	1.97
ITH3	Veneto	392	0.52	451	1.03
ITH4	Friuli-Venezia Giulia	58	0.35	130	1.84
ITH5	Emilia-Romagna	380	0.47	467	0.90
ITI1	Toscana	453	1.20	229	0.77
ITI2	Umbria	43	0.77	43	0.89
ITI3	Marche	45	0.47	62	1.48
ITI4	Lazio	400	1.14	209	1.26
LI00	Liechtenstein	23	0.58	21	0.52
LT00	Lietuva	57	1.72	24	1.09
LU00	Luxembourg	230	2.30	115	0.62
LV00	Latvija	36	1.12	34	1.45
MT00	Malta	39	1.94	7	1.72
NL11	Groningen	31	0.35	58	1.31
NL12	Friesland (NL)	22	0.37	104	4.30
NL13	Drenthe	18	0.19	24	1.18
NL21	Overijssel	121	0.60	146	1.28
NL22	Gelderland	154	0.37	273	1.16
NL23	Flevoland	68	1.05	25	1.67
NL31	Utrecht	142	0.42	158	1.10
NL32	Noord-Holland	547	0.83	342	1.13
NL33	Zuid-Holland	976	1.15	685	1.21
NL34	Zeeland	26	0.45	62	1.37
NL41	Noord-Brabant	3957	1.21	1357	0.73
NL42	Limburg (NL)	205	0.34	424	1.25
NO01	Oslo og Akershus	444	1.26	283	1.92
NO02	Hedmark og Oppland	21	1.05	13	1.66
NO03	Sør-Østlandet	124	0.72	184	2.94
NO04	Agder og Rogaland	183	0.67	220	2.11
NO05	Vestlandet	118	0.78	190	1.95
NO06	Trøndelag	286	1.17	135	1.60
NO07	Nord-Norge	9	0.36	20	0.88

NUTS-2		Digital technologies		Green technologies	
Code	Name	Patents	RCA	Patents	RCA
PL11	Łódzkie	57	0.78	30	0.96
PL12	Mazowieckie	208	0.94	125	1.36
PL21	Małopolskie	249	1.25	98	0.63
PL22	Śląskie	92	1.03	65	1.16
PL31	Lubelskie	20	0.64	27	1.36
PL32	Podkarpackie	72	1.59	16	0.85
PL33	Świętokrzyskie	12	0.29	22	1.10
PL34	Podlaskie	8	0.65	9	0.74
PL41	Wielkopolskie	79	0.97	35	1.17
PL42	Zachodniopomorskie	14	0.63	16	0.62
PL43	Lubuskie	10	0.81	9	0.75
PL51	Dolnośląskie	227	1.04	41	0.71
PL52	Opolskie	5	0.18	9	2.69
PL61	Kujawsko-Pomorskie	37	1.57	8	0.39
PL62	Warmińsko-Mazurskie	11	0.95	12	1.96
PL63	Pomorskie	149	1.65	33	1.00
PT11	Norte	222	1.00	109	1.23
PT15	Algarve	7	0.34	12	0.76
PT16	Centro (PT)	166	1.17	66	1.68
PT17	Lisboa	114	0.80	80	1.52
PT18	Alentejo	7	0.31	16	1.07
PT20	Região Autónoma dos Açores	0	0.00	7	20.45
PT30	Região Autónoma da Madeira	4	1.26	4	4.03
RO11	Nord-Vest	34	1.16	12	1.38
RO12	Centru	36	1.02	14	1.29
RO21	Nord-Est	34	1.97	5	0.21
RO22	Sud-Est	24	1.77	2	0.09
RO31	Sud - Muntenia	29	1.19	7	1.29
RO32	Bucureşti - Ilfov	135	2.41	17	1.23
RO41	Sud-Vest Oltenia	6	0.61	7	0.85
RO42	Vest	45	1.42	13	0.33
SE11	Stockholm	8739	1.62	771	0.57
SE12	Östra Mellansverige	2909	1.57	434	0.73
SE21	Småland med öarna	221	0.74	138	0.94
SE22	Sydsverige	3591	1.32	491	0.92
SE23	Västsverige	2227	1.27	779	1.01
SE31	Norra Mellansverige	256	2.40	144	1.21
SE32	Mellersta Norrland	9	0.07	82	1.77
SE33	Övre Norrland	827	1.66	70	0.49
SI03	Zahodna Slovenija	62	0.46	118	1.77
SI04	Vzhodna Slovenija	18	0.40	46	0.66
SK01	Bratislavský kraj	60	0.82	57	4.41
SK02	Západné Slovensko	28	0.60	41	1.42
SK03	Stredné Slovensko	17	0.83	26	2.44
SK04	Východné Slovensko	16	0.35	22	1.74
UKC1	Tees Valley and Durham	173	0.90	165	1.51
UKC2	Northumberland and Tyne and Wear	99	0.45	147	1.12
UKD1	Cumbria	45	0.76	24	1.09
UKD3	Greater Manchester	602	2.23	203	0.80
UKD4	Lancashire	249	1.86	113	0.56
UKD6	Cheshire	266	1.36	149	1.85
UKD7	Merseyside	81	0.37	98	0.96
UKE1	East Yorkshire and Northern Lincolnshire	52	0.44	51	1.45
UKE2	North Yorkshire	138	0.95	87	0.93
UKE3	South Yorkshire	174	0.94	108	0.82
UKE4	West Yorkshire	104	0.48	83	0.88
UKF1	Derbyshire and Nottinghamshire	150	0.58	140	0.94
UKF2	Leicestershire, Rutland and Northamptonshire	194	0.90	133	0.72
UKF3	Lincolnshire	70	0.86	40	1.12
UKG1	Herefordshire, Worcestershire and Warwickshire	147	0.51	233	1.99
UKG2	Shropshire and Staffordshire	160	1.37	78	0.90
UKG3	West Midlands	360	1.31	389	1.04
UKH1	East Anglia	2583	1.34	460	0.52
UKH2	Bedfordshire and Hertfordshire	469	2.11	181	0.78
UKH3	Essex	294	1.56	106	0.75
UKI1	Inner London	3857	2.02	400	0.43
UKI2	Outer London	934	1.81	157	0.67
UKJ1	Berkshire, Buckinghamshire and Oxfordshire	1584	1.01	788	1.10
UKJ2	Surrey, East and West Sussex	1063	1.14	304	0.74
UKJ3	Hampshire and Isle of Wight	1395	1.47	387	0.90

NUTS-2		Digital technologies		Green technologies	
Code	**Name**	**Patents**	**RCA**	**Patents**	**RCA**
UKJ4	Kent	131	0.68	68	0.51
UKK1	Gloucestershire, Wiltshire and Bristol/Bath area	1477	1.20	671	1.09
UKK2	Dorset and Somerset	190	1.08	97	0.78
UKK3	Cornwall and Isles of Scilly	38	0.74	54	3.58
UKK4	Devon	154	1.48	64	1.48
UKL1	West Wales and The Valleys	102	0.85	91	2.00
UKL2	East Wales	995	2.24	77	0.46
UKM2	Eastern Scotland	485	1.16	180	1.49
UKM3	South Western Scotland	172	1.04	75	0.94
UKM5	North Eastern Scotland	67	1.10	71	1.23
UKM6	Highlands and Islands	24	0.42	16	1.56
UKN0	Northern Ireland	185	1.00	60	1.15

Notes: This table lists both the total number of digital and green patents in each region in the columns *Number of patents*. The relative comparative advantage (*RCA*) refers to the share of digital or green patents compared to their average. Source: OECD REGPAT, own elaboration.

Table A.6: Current specialisations in twin transition technologies of European regions

NUTS-2		Top technological specialisation		
Code	Name	1st	2nd	3rd
AT11	Burgenland (AT)	Hydrogen	Green buildings	Battery technology
AT12	Niederösterreich	Hydropower	Smart farming	Drones
AT13	Wien	Greenhouse gas capture	High performance computing / Quantum computers	Fuels from waste
AT21	Kärnten	Photonics	Biofuels	Semiconductors
AT22	Steiermark	Hydrogen	Battery technology	Semiconductors
AT31	Oberösterreich	Robotics (autonomous)	Recycling technologies	Waste management
AT32	Salzburg	Electric vehicles	Biofuels	HVAC Systems
AT33	Tirol	Biofuels	Fuels from waste	Hydrogen
AT34	Vorarlberg	Green buildings	Smart farming	Waste management
BE10	Région de Bruxelles-Capitale / Brussels Hoofdstedelijk Gewest	Fuels from waste	Waste management	Hydrogen
BE21	Prov. Antwerpen	Recycling technologies	Waste management	Advanced Sustainable Materials
BE22	Prov. Limburg (BE)	Fuels from waste	Recycling technologies	Photonics
BE23	Prov. Oost-Vlaanderen	Biocides	Smart farming	Advanced Sustainable Materials
BE24	Prov. Vlaams-Brabant	Waste management	Photonics	Advanced materials/nanomaterials
BE25	Prov. West-Vlaanderen	Advanced Sustainable Materials	Smart farming	Recycling technologies
BE31	Prov. Brabant Wallon	Advanced Sustainable Materials	Advanced materials/nanomaterials	Fuels from waste
BE32	Prov. Hainaut	Advanced Sustainable Materials	Fuels from waste	Advanced materials/nanomaterials
BE33	Prov. Liège	Greenhouse gas capture	Smart farming	Biocides
BE34	Prov. Luxembourg (BE)	Advanced materials/nanomaterials	Advanced Sustainable Materials	Waste management
BE35	Prov. Namur	Fuels from waste	Advanced Sustainable Materials	Waste management
BG31	Severozapaden			
BG32	Severen tsentralen			
BG33	Severoiztochen			
BG34	Yugoiztochen			
BG41	Yugozapaden	Hydropower	Waste management	Recycling technologies
BG42	Yuzhen tsentralen	Waste management		
CH01	Région lémanique	Geothermal energy	Cryptography and distributed ledger technology	High performance computing / Quantum computers
CH02	Espace Mittelland	Geothermal energy	Advanced materials/nanomaterials	Solar energy
CH03	Nordwestschweiz	Biocides	Advanced materials/nanomaterials	Smart grids
CH04	Zürich	Artificial intelligence	Greenhouse gas capture	Geothermal energy
CH05	Ostschweiz	Hydropower	Additive manufacturing (3D printing)	Photonics
CH06	Zentralschweiz	Hydropower	Advanced Sustainable Materials	Robotics (autonomous)
CH07	Ticino	Greenhouse gas capture	Efficient power & combustion	Advanced materials/nanomaterials
CY00	Kýpros	Advanced materials/nanomaterials	Artificial intelligence	Big data
CZ01	Praha	Nuclear energy	HVAC Systems	Advanced materials/nanomaterials
CZ02	Střední Čechy	HVAC Systems	Biofuels	Cybersecurity
CZ03	Jihozápad	Nuclear energy	Recycling technologies	Waste management
CZ04	Severozápad	Recycling technologies	Cryptography and distributed ledger technology	Advanced Sustainable Materials
CZ05	Severovýchod	HVAC Systems	Advanced materials/nanomaterials	Recycling technologies
CZ06	Jihovýchod	Nuclear energy	Recycling technologies	Advanced materials/nanomaterials
CZ07	Střední Morava	Advanced materials/nanomaterials	Fuels from waste	Biocides

NUTS-2		Top technological specialisation		
Code	Name	1st	2nd	3rd
CZ08	Moravskoslezsko	HVAC Systems	Additive manufacturing (3D printing)	Advanced materials/nanomaterials
DE11	Stuttgart	Hydrogen	Autonomous mobility	Battery technology
DE12	Karlsruhe	Electric vehicles	Battery technology	Hydrogen
DE13	Freiburg	Water treatment	Electric vehicles	Bio fertilizers
DE14	Tübingen	Autonomous mobility	Hydrogen	Battery technology
DE21	Oberbayern	Heat pumps	Robotics (autonomous)	HVAC Systems
DE22	Niederbayern	Semiconductors	Solar energy	Photonics
DE23	Oberpfalz	Semiconductors	Photonics	Solar energy
DE24	Oberfranken	Nuclear energy	Efficient power & combustion	HVAC Systems
DE25	Mittelfranken	Efficient power & combustion	Nuclear energy	Smart grids
DE26	Unterfranken	Electric vehicles	Nuclear energy	Semiconductors
DE27	Schwaben	Robotics (autonomous)	Additive manufacturing (3D printing)	Battery technology
DE30	Berlin	Additive manufacturing (3D printing)	Smart grids	High performance computing / Quantum computers
DE40	Brandenburg	Water treatment	Additive manufacturing (3D printing)	High performance computing / Quantum computers
DE50	Bremen	Wind energy	Smart grids	Drones
DE60	Hamburg	Wind energy	Drones	Efficient power & combustion
DE71	Darmstadt	Broadband	Semiconductors	Biocides
DE72	Gießen	Robotics (autonomous)	Water treatment	Smart farming
DE73	Kassel	Smart grids	Efficient power & combustion	Solar energy
DE80	Mecklenburg-Vorpommern	Wind energy	Efficient power & combustion	Biocides
DE91	Braunschweig	Hydrogen	HVAC Systems	Battery technology
DE92	Hannover	Autonomous mobility	Robotics (autonomous)	Greenhouse gas capture
DE93	Lüneburg	Efficient power & combustion	Wind energy	Biofuels
DE94	Weser-Ems	Wind energy	Smart grids	Hydropower
DEA1	Düsseldorf	Biocides	Water treatment	Advanced Sustainable Materials
DEA2	Köln	Biocides	Advanced Sustainable Materials	Smart farming
DEA3	Münster	Bio fertilizers	Biocides	Water treatment
DEA4	Detmold	Electric vehicles	Heat pumps	Drones
DEA5	Arnsberg	Electric vehicles	Water treatment	Efficient power & combustion
DEB1	Koblenz	Bio fertilizers	Biocides	Advanced Sustainable Materials
DEB2	Trier	Advanced Sustainable Materials	Robotics (autonomous)	Recycling technologies
DEB3	Rheinhessen-Pfalz	Biocides	Sustainable packaging	Advanced materials/nanomaterials
DEC0	Saarland	Hydropower	Advanced Sustainable Materials	Advanced materials/nanomaterials
DED2	Dresden	Semiconductors	Solar energy	Photonics
DED4	Chemnitz	Efficient power & combustion	Semiconductors	Robotics (autonomous)
DED5	Leipzig	Solar energy	Photonics	Fuels from waste
DEE0	Sachsen-Anhalt	Solar energy	Bio fertilizers	Semiconductors
DEF0	Schleswig-Holstein	Wind energy	Hydrogen	Additive manufacturing (3D printing)
DEG0	Thüringen	Photonics	Bio fertilizers	Virtual Reality and Augmented Reality
DK01	Hovedstaden	Biofuels	Fuels from waste	Greenhouse gas capture
DK02	Sjælland	Greenhouse gas capture	Fuels from waste	Wind energy
DK03	Syddanmark	Wind energy	Robotics (autonomous)	HVAC Systems
DK04	Midtjylland	Wind energy	Smart grids	Efficient power & combustion
DK05	Nordjylland	Wind energy	5G	Internet of things
EE00	Eesti	Autonomous mobility	Water treatment	Artificial intelligence

NUTS-2		Top technological specialisation		
Code	Name	1st	2nd	3rd
EL30	Attiki	Cloud and edge computing	Cybersecurity	Fuels from waste
EL41	Voreio Aigaio	Virtual Reality and Augmented Reality		
EL42	Notio Aigaio			
EL43	Kriti	Electric vehicles		
EL51	Anatoliki Makedonia, Thraki			
EL52	Kentriki Makedonia	Biocides	Cybersecurity	Battery technology
EL53	Dytiki Makedonia			
EL54	Thessalia	Advanced materials/ nanomaterials		
EL61	Ipeiros			
EL62	Ionia Nisia			
EL63	Dytiki Ellada	Cloud and edge computing	Big data	Advanced Sustainable Materials
EL64	Sterea Ellada			
EL65	Peloponnisos			
ES11	Galicia	Advanced materials/ nanomaterials	Smart farming	High performance computing / Quantum computers
ES12	Principado de Asturias	Greenhouse gas capture	Advanced materials/nanomaterials	Drones
ES13	Cantabria	Greenhouse gas capture	Wind energy	
ES21	País Vasco	Marine energy	Wind energy	Advanced materials/nanomaterials
ES22	Comunidad Foral de Navarra	Wind energy	Smart grids	Efficient power & combustion
ES23	La Rioja	Advanced Sustainable Materials	Solar energy	Big data
ES24	Aragón	Bio fertilizers	Biocides	Waste management
ES30	Comunidad de Madrid	Cloud and edge computing	Cybersecurity	Advanced materials/nanomaterials
ES41	Castilla y León	Hydropower	Water treatment	Waste management
ES42	Castilla-La Mancha	Wind energy	Advanced materials/nanomaterials	Waste management
ES43	Extremadura			
ES51	Cataluña	Additive manufacturing (3D printing)	Advanced materials/nanomaterials	Greenhouse gas capture
ES52	Comunidad Valenciana	Sustainable packaging	Fuels from waste	Advanced materials/nanomaterials
ES53	Illes Balears	HVAC Systems	Green buildings	Smart grids
ES61	Andalucía	Bio fertilizers	Fuels from waste	Marine energy
ES62	Región de Murcia	Hydropower	Bio fertilizers	Solar energy
ES64	Ciudad Autónoma de Melilla			
ES70	Canarias	Water treatment	Biocides	Waste management
FI19	Länsi-Suomi	Virtual Reality and Augmented Reality	Biofuels	Sustainable packaging
FI1B	Helsinki-Uusimaa	5G	Bio fertilizers	Internet of things
FI1C	Etelä-Suomi	Broadband	Bio fertilizers	Sustainable packaging
FI1D	Pohjois- ja Itä-Suomi	5G	Internet of things	Bio fertilizers
FI20	Åland			
FR10	Île-de-France	HVAC Systems	Water treatment	Nuclear energy
FR21	Champagne-Ardenne	Fuels from waste	Biofuels	Waste management
FR22	Picardie	Advanced Sustainable Materials	Smart farming	Electric vehicles
FR23	Haute-Normandie	HVAC Systems	Advanced Sustainable Materials	Additive manufacturing (3D printing)
FR24	Centre	Advanced Sustainable Materials	Battery technology	Hydrogen
FR25	Basse-Normandie	Greenhouse gas capture	Fuels from waste	Waste management
FR26	Bourgogne	Nuclear energy	Photonics	Biocides
FR30	Nord - Pas-de-Calais	Nuclear energy	Greenhouse gas capture	Electric vehicles
FR41	Lorraine	Greenhouse gas capture	Bio fertilizers	Advanced Sustainable Materials
FR42	Alsace	Advanced materials/nanomaterials	Smart grids	Electric vehicles
FR43	Franche-Comté	Sustainable packaging	Hydrogen	Electric vehicles
FR51	Pays de la Loire	Marine energy	Nuclear energy	Battery technology

NUTS-2		Top technological specialisation		
Code	Name	1st	2nd	3rd
FR52	Bretagne	Bio fertilizers	Virtual Reality and Augmented Reality	High performance computing / Quantum computers
FR53	Poitou-Charentes	Marine energy	Water treatment	Electric vehicles
FR61	Aquitaine	Geothermal energy	Biocides	Drones
FR62	Midi-Pyrénées	Geothermal energy	Drones	Heat pumps
FR63	Limousin	Recycling technologies	Biocides	Photonics
FR71	Rhône-Alpes	Nuclear energy	Hydropower	Semiconductors
FR72	Auvergne	Additive manufacturing (3D printing)	Fuels from waste	Advanced Sustainable Materials
FR81	Languedoc-Roussillon	Nuclear energy	Bio fertilizers	Recycling technologies
FR82	Provence-Alpes-Côte d'Azur	Nuclear energy	Cybersecurity	Cryptography and distributed ledger technology
FR83	Corse			
FRY1	Guadeloupe			
FRY2	Martinique			
FRY3	Guyane			
FRY4	Réunion	Solar energy	Internet of things	Big data
HR03	Jadranska Hrvatska	Electric vehicles		
HR04	Kontinentalna Hrvatska	Solar energy	Autonomous mobility	Artificial intelligence
HU10	Közép-Magyarország	Cloud and edge computing	Bio fertilizers	Robotics (autonomous)
HU21	Közép-Dunántúl	Waste management	Cloud and edge computing	Autonomous mobility
HU22	Nyugat-Dunántúl	Robotics (autonomous)	Waste management	Biofuels
HU23	Dél-Dunántúl	Autonomous mobility	Artificial intelligence	Internet of things
HU31	Észak-Magyarország	Cloud and edge computing	Virtual Reality and Augmented Reality	Internet of things
HU32	Észak-Alföld	Biocides	Waste management	Artificial intelligence
HU33	Dél-Alföld	Robotics (autonomous)	Cloud and edge computing	Big data
IE01	Border, Midland and Western	Virtual Reality and Augmented Reality	Artificial intelligence	Cloud and edge computing
IE02	Southern and Eastern	Broadband	Marine energy	Cryptography and distributed ledger technology
IS01	Höfuðborgarsvæði	HVAC Systems	Robotics (autonomous)	Green buildings
IS02	Landsbyggð	Smart farming	Biocides	
ITC1	Piemonte	Waste management	HVAC Systems	Marine energy
ITC2	Valle d'Aosta/Vallée d'Aoste	Electric vehicles	Green buildings	
ITC3	Liguria	Nuclear energy	High performance computing / Quantum computers	Efficient power & combustion
ITC4	Lombardia	Sustainable packaging	Geothermal energy	Greenhouse gas capture
ITF1	Abruzzo	Waste management	Efficient power & combustion	Recycling technologies
ITF2	Molise	Advanced Sustainable Materials		
ITF3	Campania	Cybersecurity	Cloud and edge computing	Biocides
ITF4	Puglia	Marine energy	Advanced materials/nanomaterials	Fuels from waste
ITF5	Basilicata	Big data		
ITF6	Calabria	Smart farming	Advanced materials/nanomaterials	Hydrogen
ITG1	Sicilia	Cryptography and distributed ledger technology	Cybersecurity	Internet of things
ITG2	Sardegna	Recycling technologies	HVAC Systems	Solar energy
ITH1	Provincia Autonoma di Bolzano/Bozen	Fuels from waste	Biofuels	Additive manufacturing (3D printing)
ITH2	Provincia Autonoma di Trento	Recycling technologies	HVAC Systems	Waste management
ITH3	Veneto	Green buildings	Waste management	Smart farming
ITH4	Friuli-Venezia Giulia	Heat pumps	Fuels from waste	Greenhouse gas capture
ITH5	Emilia-Romagna	Sustainable packaging	Marine energy	Hydropower
ITI1	Toscana	High performance computing / Quantum computers	Robotics (autonomous)	Water treatment
ITI2	Umbria	Solar energy	Robotics (autonomous)	Smart farming

NUTS-2		Top technological specialisation		
Code	Name	1st	2nd	3rd
ITI3	Marche	HVAC Systems	Green buildings	Advanced materials/nanomaterials
ITI4	Lazio	Bio fertilizers	Waste management	Greenhouse gas capture
LI00	Liechtenstein	Advanced Sustainable Materials	Photonics	Semiconductors
LT00	Lietuva	Drones	Photonics	Autonomous mobility
LU00	Luxembourg	Advanced Sustainable Materials	Recycling technologies	High performance computing / Quantum computers
LV00	Latvija	Drones	Biofuels	Smart farming
MT00	Malta	Artificial intelligence	Cryptography and distributed ledger technology	Virtual Reality and Augmented Reality
NL11	Groningen	Fuels from waste	Biofuels	Waste management
NL12	Friesland (NL)	Sustainable packaging	Recycling technologies	Fuels from waste
NL13	Drenthe	HVAC Systems	Green buildings	Wind energy
NL21	Overijssel	Biofuels	Waste management	Green buildings
NL22	Gelderland	Bio fertilizers	Smart farming	Fuels from waste
NL23	Flevoland	Semiconductors	Photonics	Advanced Sustainable Materials
NL31	Utrecht	Sustainable packaging	Recycling technologies	Wind energy
NL32	Noord-Holland	Greenhouse gas capture	Heat pumps	Recycling technologies
NL33	Zuid-Holland	Advanced materials/nanomaterials	High performance computing / Quantum computers	Fuels from waste
NL34	Zeeland	Recycling technologies	Smart farming	Advanced Sustainable Materials
NL41	Noord-Brabant	Smart farming	Green buildings	Virtual Reality and Augmented Reality
NL42	Limburg (NL)	Fuels from waste	Advanced Sustainable Materials	Heat pumps
NO01	Oslo og Akershus	Marine energy	Hydropower	Smart farming
NO02	Hedmark og Oppland	Biofuels	Cloud and edge computing	Cybersecurity
NO03	Sør-Østlandet	Hydropower	Geothermal energy	Marine energy
NO04	Agder og Rogaland	Marine energy	Hydropower	Smart farming
NO05	Vestlandet	Marine energy	Smart farming	Drones
NO06	Trøndelag	Greenhouse gas capture	Marine energy	Smart grids
NO07	Nord-Norge	Smart farming	Autonomous mobility	
PL11	Łódzkie	Photonics	Waste management	Recycling technologies
PL12	Mazowieckie	High performance computing / Quantum computers	Efficient power & combustion	Waste management
PL21	Małopolskie	Cloud and edge computing	Advanced materials/nanomaterials	Drones
PL22	Śląskie	Drones	Recycling technologies	Waste management
PL31	Lubelskie	Wind energy	Biofuels	Solar energy
PL32	Podkarpackie	Drones	Cloud and edge computing	Virtual Reality and Augmented Reality
PL33	Świętokrzyskie	Advanced Sustainable Materials	Battery technology	Big data
PL34	Podlaskie	Biofuels		
PL41	Wielkopolskie	Additive manufacturing (3D printing)	5G	Smart farming
PL42	Zachodniopomorskie	Battery technology	Advanced Sustainable Materials	Electric vehicles
PL43	Lubuskie	Battery technology	Electric vehicles	Big data
PL51	Dolnośląskie	5G	Big data	Internet of things
PL52	Opolskie	Recycling technologies		
PL61	Kujawsko-Pomorskie	Advanced materials/nanomaterials	Cryptography and distributed ledger technology	Photonics
PL62	Warmińsko-Mazurskie	Additive manufacturing (3D printing)	Recycling technologies	
PL63	Pomorskie	High performance computing / Quantum computers	HVAC Systems	Cloud and edge computing
PT11	Norte	Autonomous mobility	Greenhouse gas capture	Advanced materials/nanomaterials

NUTS-2		Top technological specialisation		
Code	**Name**	**1st**	**2nd**	**3rd**
PT15	Algarve	Electric vehicles		
PT16	Centro (PT)	Water treatment	Cloud and edge computing	Cryptography and distributed ledger technology
PT17	Lisboa	Marine energy	Waste management	Recycling technologies
PT18	Alentejo	Waste management		
PT20	Região Autónoma dos Açores			
PT30	Região Autónoma da Madeira			
RO11	Nord-Vest	Cloud and edge computing	Cybersecurity	Big data
RO12	Centru	Artificial intelligence	Virtual Reality and Augmented Reality	Solar energy
RO21	Nord-Est	Cloud and edge computing	Cybersecurity	Artificial intelligence
RO22	Sud-Est	Artificial intelligence	Cybersecurity	Big data
RO31	Sud - Muntenia	Cloud and edge computing	Artificial intelligence	Cybersecurity
RO32	Bucureşti - Ilfov	Drones	Cryptography and distributed ledger technology	Cybersecurity
RO41	Sud-Vest Oltenia	Electric vehicles		
RO42	Vest	Virtual Reality and Augmented Reality	Artificial intelligence	Cryptography and distributed ledger technology
SE11	Stockholm	5G	Internet of things	Big data
SE12	Östra Mellansverige	5G	Nuclear energy	Robotics (autonomous)
SE21	Småland med öarna	Autonomous mobility	HVAC Systems	Green buildings
SE22	Sydsverige	5G	Internet of things	Big data
SE23	Västsverige	5G	Hydropower	Internet of things
SE31	Norra Mellansverige	Broadband	Smart grids	Efficient power & combustion
SE32	Mellersta Norrland	Fuels from waste	Biofuels	Waste management
SE33	Övre Norrland	5G	Internet of things	Big data
SI03	Zahodna Slovenija	Hydropower	Electric vehicles	Green buildings
SI04	Vzhodna Slovenija	Electric vehicles	Smart farming	Biocides
SK01	Bratislavský kraj	Hydropower	Bio fertilizers	Fuels from waste
SK02	Západné Slovensko	Waste management	Recycling technologies	HVAC Systems
SK03	Stredné Slovensko	Waste management	Biofuels	Artificial intelligence
SK04	Východné Slovensko	Electric vehicles	Advanced Sustainable Materials	5G
UKC1	Tees Valley and Durham	Fuels from waste	Advanced materials/nanomaterials	Marine energy
UKC2	Northumberland and Tyne and Wear	Water treatment	Waste management	Efficient power & combustion
UKD1	Cumbria	Advanced Sustainable Materials	Photonics	Cloud and edge computing
UKD3	Greater Manchester	Drones	High performance computing / Quantum computers	Autonomous mobility
UKD4	Lancashire	Drones	Robotics (autonomous)	High performance computing / Quantum computers
UKD6	Cheshire	Nuclear energy	Marine energy	Bio fertilizers
UKD7	Merseyside	Biocides	Waste management	Recycling technologies
UKE1	East Yorkshire and Northern Lincolnshire	Biocides	Green buildings	Advanced materials/nanomaterials
UKE2	North Yorkshire	Fuels from waste	High performance computing / Quantum computers	Smart farming
UKE3	South Yorkshire	Wind energy	Additive manufacturing (3D printing)	Waste management
UKE4	West Yorkshire	Water treatment	Greenhouse gas capture	Biocides
UKF1	Derbyshire and Nottinghamshire	Nuclear energy	Waste management	Smart grids
UKF2	Leicestershire, Rutland and Northamptonshire	Hydrogen	Drones	Photonics
UKF3	Lincolnshire	Water treatment	Efficient power & combustion	Additive manufacturing (3D printing)
UKG1	Herefordshire, Worcestershire and Warwickshire	Nuclear energy	Hydropower	Smart farming
UKG2	Shropshire and Staffordshire	Smart grids	Efficient power & combustion	Additive manufacturing (3D printing)

NUTS-2		Top technological specialisation		
Code	**Name**	**1st**	**2nd**	**3rd**
UKG3	West Midlands	Sustainable packaging	Autonomous mobility	Electric vehicles
UKH1	East Anglia	Semiconductors	High performance computing / Quantum computers	Cryptography and distributed ledger technology
UKH2	Bedfordshire and Hertfordshire	Broadband	Greenhouse gas capture	Drones
UKH3	Essex	High performance computing / Quantum computers	Cryptography and distributed ledger technology	Additive manufacturing (3D printing)
UKI1	Inner London	Broadband	Artificial intelligence	Cryptography and distributed ledger technology
UKI2	Outer London	Cryptography and distributed ledger technology	Cloud and edge computing	Cybersecurity
UKJ1	Berkshire, Buckinghamshire and Oxfordshire	Nuclear energy	Biocides	Advanced materials/ nanomaterials
UKJ2	Surrey, East and West Sussex	Sustainable packaging	Cryptography and distributed ledger technology	Artificial intelligence
UKJ3	Hampshire and Isle of Wight	Wind energy	Drones	5G
UKJ4	Kent	Virtual Reality and Augmented Reality	Waste management	Photonics
UKK1	Gloucestershire, Wiltshire and Bristol/Bath area	Marine energy	Cybersecurity	Smart grids
UKK2	Dorset and Somerset	Drones	Cryptography and distributed ledger technology	Green buildings
UKK3	Cornwall and Isles of Scilly	Advanced materials/nanomaterials	Fuels from waste	Biofuels
UKK4	Devon	High performance computing / Quantum computers	Photonics	Semiconductors
UKL1	West Wales and The Valleys	Marine energy	Drones	Solar energy
UKL2	East Wales	Cryptography and distributed ledger technology	Cybersecurity	Internet of things
UKM2	Eastern Scotland	Marine energy	Hydropower	High performance computing / Quantum computers
UKM3	South Western Scotland	Marine energy	High performance computing / Quantum computers	Water treatment
UKM5	North Eastern Scotland	Marine energy	Hydropower	Water treatment
UKM6	Highlands and Islands	Marine energy	Smart farming	Cryptography and distributed ledger technology
UKN0	Northern Ireland	Greenhouse gas capture	Recycling technologies	Fuels from waste

Notes: The *Top technological specialisations* refer to the technologies with the highest RCA in each region. For the ranking, we only consider technologies in which a region has at least three patent applications recorded (from 2017 to 2021). Sources: OECD REGPAT, own elaboration.

Table A.7: Highest potential in developing twin transition technologies of European regions

NUTS-2		Top technological opportunities		
Code	**Name**	**1st**	**2nd**	**3rd**
AT11	Burgenland (AT)	Greenhouse gas capture	Hydrogen	Battery technology
AT12	Niederösterreich	Geothermal energy	Heat pumps	Marine energy
AT13	Wien	Artificial intelligence	Virtual Reality and Augmented Reality	Greenhouse gas capture
AT21	Kärnten	Wind energy	Green buildings	Solar energy
AT22	Steiermark	Battery technology	Hydrogen	Geothermal energy
AT31	Oberösterreich	Wind energy	Robotics (autonomous)	Sustainable packaging
AT32	Salzburg	Greenhouse gas capture	Electric vehicles	Virtual Reality and Augmented Reality
AT33	Tirol	Sustainable packaging	Biofuels	Additive manufacturing (3D printing)
AT34	Vorarlberg	Sustainable packaging	Robotics (autonomous)	Electric vehicles
BE10	Région de Bruxelles-Capitale / Brussels Hoofdstedelijk Gewest	Hydrogen	Fuels from waste	Biofuels
BE21	Prov. Antwerpen	Sustainable packaging	Recycling technologies	Wind energy
BE22	Prov. Limburg (BE)	Sustainable packaging	Greenhouse gas capture	Recycling technologies
BE23	Prov. Oost-Vlaanderen	Bio fertilizers	Sustainable packaging	Biocides
BE24	Prov. Vlaams-Brabant	Biocides	Sustainable packaging	Advanced materials/ nanomaterials
BE25	Prov. West-Vlaanderen	Sustainable packaging	Advanced sustainable materials	Geothermal energy
BE31	Prov. Brabant Wallon	Greenhouse gas capture	Advanced materials/ nanomaterials	Fuels from waste
BE32	Prov. Hainaut	Greenhouse gas capture	Advanced materials/ nanomaterials	Advanced Sustainable Materials
BE33	Prov. Liège	Greenhouse gas capture	Bio fertilizers	Biocides
BE34	Prov. Luxembourg (BE)	Additive manufacturing (3D printing)	Sustainable packaging	Semiconductors
BE35	Prov. Namur	Bio fertilizers	Biocides	Sustainable packaging
BG31	Severozapaden	Sustainable packaging	Hydrogen	Recycling technologies
BG32	Severen tsentralen	Sustainable packaging	Recycling technologies	Hydrogen
BG33	Severoiztochen	Sustainable packaging	Cryptography and distributed ledger technology	Cybersecurity
BG34	Yugoiztochen	Cybersecurity	Advanced Sustainable Materials	Autonomous mobility
BG41	Yugozapaden	Marine energy	Hydropower	Wind energy
BG42	Yuzhen tsentralen	Sustainable packaging	Wind energy	Robotics (autonomous)
CH01	Région lémanique	Biocides	Artificial intelligence	Geothermal energy
CH02	Espace Mittelland	Semiconductors	Geothermal energy	Photonics
CH03	Nordwestschweiz	Biocides	Semiconductors	Efficient power & combustion
CH04	Zürich	Artificial intelligence	Virtual Reality and Augmented Reality	High performance computing / Quantum computers
CH05	Ostschweiz	Additive manufacturing (3D printing)	Robotics (autonomous)	Geothermal energy
CH06	Zentralschweiz	Marine energy	Geothermal energy	Robotics (autonomous)
CH07	Ticino	Greenhouse gas capture	Bio fertilizers	Sustainable packaging
CY00	Kýpros	Artificial intelligence	Virtual Reality and Augmented Reality	Fuels from waste
CZ01	Praha	Cryptography and distributed ledger technology	Cybersecurity	Cloud and edge computing
CZ02	Střední Čechy	Cybersecurity	Cloud and edge computing	Cryptography and distributed ledger technology
CZ03	Jihozápad	Sustainable packaging	Nuclear energy	Drones
CZ04	Severozápad	Biocides	Nuclear energy	Advanced Sustainable Materials
CZ05	Severovýchod	Nuclear energy	HVAC Systems	Biocides
CZ06	Jihovýchod	Nuclear energy	Water treatment	Biocides
CZ07	Střední Morava	Biocides	Nuclear energy	Sustainable packaging
CZ08	Moravskoslezsko	Greenhouse gas capture	HVAC Systems	Heat pumps

NUTS-2		Top technological opportunities		
Code	Name	1st	2nd	3rd
DE11	Stuttgart	Electric vehicles	Battery technology	Robotics (autonomous)
DE12	Karlsruhe	Electric vehicles	Robotics (autonomous)	Battery technology
DE13	Freiburg	Robotics (autonomous)	Electric vehicles	Semiconductors
DE14	Tübingen	Electric vehicles	Heat pumps	Battery technology
DE21	Oberbayern	5G	Broadband	Cybersecurity
DE22	Niederbayern	Electric vehicles	Photonics	Additive manufacturing (3D printing)
DE23	Oberpfalz	Photonics	Semiconductors	Robotics (autonomous)
DE24	Oberfranken	Electric vehicles	HVAC Systems	Battery technology
DE25	Mittelfranken	Smart grids	Nuclear energy	Battery technology
DE26	Unterfranken	Additive manufacturing (3D printing)	Nuclear energy	Electric vehicles
DE27	Schwaben	Robotics (autonomous)	Electric vehicles	Additive manufacturing (3D printing)
DE30	Berlin	Broadband	Cybersecurity	Cryptography and distributed ledger technology
DE40	Brandenburg	Photonics	Additive manufacturing (3D printing)	Semiconductors
DE50	Bremen	Wind energy	Additive manufacturing (3D printing)	Smart grids
DE60	Hamburg	Wind energy	Hydropower	Drones
DE71	Darmstadt	Greenhouse gas capture	Nuclear energy	Biocides
DE72	Gießen	Sustainable packaging	Recycling technologies	Bio fertilizers
DE73	Kassel	Smart grids	Green buildings	Sustainable packaging
DE80	Mecklenburg-Vorpommern	Bio fertilizers	Biocides	Wind energy
DE91	Braunschweig	Drones	Autonomous mobility	Electric vehicles
DE92	Hannover	Robotics (autonomous)	Electric vehicles	Autonomous mobility
DE93	Lüneburg	Wind energy	Additive manufacturing (3D printing)	Geothermal energy
DE94	Weser-Ems	Wind energy	Marine energy	Hydropower
DEA1	Düsseldorf	Additive manufacturing (3D printing)	Biocides	Efficient power & combustion
DEA2	Köln	Biocides	Additive manufacturing (3D printing)	Advanced Sustainable Materials
DEA3	Münster	Bio fertilizers	Biocides	Sustainable packaging
DEA4	Detmold	Green buildings	Electric vehicles	HVAC Systems
DEA5	Arnsberg	Additive manufacturing (3D printing)	Electric vehicles	Water treatment
DEB1	Koblenz	Water treatment	Biocides	Advanced Sustainable Materials
DEB2	Trier	Drones	Robotics (autonomous)	Sustainable packaging
DEB3	Rheinhessen-Pfalz	Bio fertilizers	Biocides	Greenhouse gas capture
DEC0	Saarland	Marine energy	Photonics	Geothermal energy
DED2	Dresden	Semiconductors	Photonics	Additive manufacturing (3D printing)
DED4	Chemnitz	HVAC Systems	Additive manufacturing (3D printing)	Heat pumps
DED5	Leipzig	Greenhouse gas capture	Bio fertilizers	HVAC Systems
DEE0	Sachsen-Anhalt	Greenhouse gas capture	Bio fertilizers	Heat pumps
DEF0	Schleswig-Holstein	Additive manufacturing (3D printing)	Wind energy	Geothermal energy
DEG0	Thüringen	Photonics	Advanced materials/nanomaterials	Semiconductors
DK01	Hovedstaden	Greenhouse gas capture	Geothermal energy	Fuels from waste
DK02	Sjælland	Greenhouse gas capture	Wind energy	Fuels from waste
DK03	Syddanmark	Wind energy	Robotics (autonomous)	Green buildings
DK04	Midtjylland	Wind energy	Green buildings	Smart grids
DK05	Nordjylland	5G	Wind energy	Broadband
EE00	Eesti	Artificial intelligence	Virtual Reality and Augmented Reality	Cryptography and distributed ledger technology
EL30	Attiki	5G	Cryptography and distributed ledger technology	Cloud and edge computing

NUTS-2		Top technological opportunities		
Code	Name	1st	2nd	3rd
EL41	Voreio Aigaio	Cloud and edge computing	Cryptography and distributed ledger technology	Virtual Reality and Augmented Reality
EL42	Notio Aigaio	Water treatment	Smart farming	Biocides
EL43	Kriti	Sustainable packaging	Bio fertilizers	Additive manufacturing (3D printing)
EL51	Anatoliki Makedonia, Thraki	Biocides	Sustainable packaging	Hydrogen
EL52	Kentriki Makedonia	Green buildings	Biocides	Heat pumps
EL53	Dytiki Makedonia	Drones	Sustainable packaging	Recycling technologies
EL54	Thessalia	Hydrogen	Advanced materials/nanomaterials	Battery technology
EL61	Ipeiros	Artificial intelligence	Smart farming	Virtual Reality and Augmented Reality
EL62	Ionia Nisia	Biocides	Advanced materials/nanomaterials	Advanced Sustainable Materials
EL63	Dytiki Ellada	Wind energy	5G	Cloud and edge computing
EL64	Sterea Ellada	Drones	Semiconductors	Solar energy
EL65	Peloponnisos	Wind energy	Biocides	Artificial intelligence
ES11	Galicia	Marine energy	Biocides	Advanced materials/nanomaterials
ES12	Principado de Asturias	Marine energy	Hydropower	Greenhouse gas capture
ES13	Cantabria	Wind energy	Greenhouse gas capture	Nuclear energy
ES21	País Vasco	Marine energy	Hydropower	Wind energy
ES22	Comunidad Foral de Navarra	Geothermal energy	Wind energy	Green buildings
ES23	La Rioja	Cybersecurity	Advanced materials/nanomaterials	Advanced Sustainable Materials
ES24	Aragón	Bio fertilizers	Biocides	Green buildings
ES30	Comunidad de Madrid	Cybersecurity	Cryptography and distributed ledger technology	Cloud and edge computing
ES41	Castilla y León	Marine energy	Geothermal energy	Biocides
ES42	Castilla-La Mancha	Wind energy	Drones	Bio fertilizers
ES43	Extremadura	Robotics (autonomous)	Battery technology	Virtual Reality and Augmented Reality
ES51	Cataluña	Additive manufacturing (3D printing)	Robotics (autonomous)	Virtual Reality and Augmented Reality
ES52	Comunidad Valenciana	Biocides	Bio fertilizers	Greenhouse gas capture
ES53	Illes Balears	Cloud and edge computing	Cybersecurity	Cryptography and distributed ledger technology
ES61	Andalucía	Biocides	Marine energy	Bio fertilizers
ES62	Región de Murcia	Biocides	Bio fertilizers	Sustainable packaging
ES64	Ciudad Autónoma de Melilla	Cryptography and distributed ledger technology	Cybersecurity	Cloud and edge computing
ES70	Canarias	Wind energy	Bio fertilizers	Sustainable packaging
FI19	Länsi-Suomi	5G	Cloud and edge computing	Cybersecurity
FI1B	Helsinki-Uusimaa	5G	Broadband	Cloud and edge computing
FI1C	Etelä-Suomi	Bio fertilizers	Fuels from waste	Waste management
FI1D	Pohjois- ja Itä-Suomi	Broadband	5G	Bio fertilizers
FI20	Åland	5G	Cloud and edge computing	Cryptography and distributed ledger technology
FR10	Île-de-France	Cryptography and distributed ledger technology	Cybersecurity	Cloud and edge computing
FR21	Champagne-Ardenne	Fuels from waste	Bio fertilizers	Marine energy
FR22	Picardie	Advanced Sustainable Materials	Biocides	Smart farming
FR23	Haute-Normandie	Sustainable packaging	Water treatment	Additive manufacturing (3D printing)
FR24	Centre	Sustainable packaging	HVAC Systems	Battery technology
FR25	Basse-Normandie	Greenhouse gas capture	Biocides	Sustainable packaging
FR26	Bourgogne	Biocides	Advanced Sustainable Materials	Bio fertilizers

NUTS-2		Top technological opportunities		
Code	Name	1st	2nd	3rd
FR30	Nord - Pas-de-Calais	Geothermal energy	Nuclear energy	Recycling technologies
FR41	Lorraine	Greenhouse gas capture	Additive manufacturing (3D printing)	Biocides
FR42	Alsace	Electric vehicles	Hydrogen	Battery technology
FR43	Franche-Comté	Electric vehicles	Water treatment	Hydrogen
FR51	Pays de la Loire	Nuclear energy	Bio fertilizers	Biocides
FR52	Bretagne	5G	Broadband	Cloud and edge computing
FR53	Poitou-Charentes	Bio fertilizers	Biocides	Greenhouse gas capture
FR61	Aquitaine	Biocides	Bio fertilizers	Fuels from waste
FR62	Midi-Pyrénées	Drones	Bio fertilizers	Geothermal energy
FR63	Limousin	Biocides	HVAC Systems	Sustainable packaging
FR71	Rhône-Alpes	Greenhouse gas capture	Sustainable packaging	Advanced materials/nanomaterials
FR72	Auvergne	Additive manufacturing (3D printing)	Sustainable packaging	Advanced Sustainable Materials
FR81	Languedoc-Roussillon	Bio fertilizers	Greenhouse gas capture	Biocides
FR82	Provence-Alpes-Côte d'Azur	Cryptography and distributed ledger technology	Cybersecurity	Nuclear energy
FR83	Corse	Cryptography and distributed ledger technology	5G	Biocides
FRY1	Guadeloupe	5G	Cybersecurity	Cryptography and distributed ledger technology
FRY2	Martinique	Cybersecurity	Cryptography and distributed ledger technology	Cloud and edge computing
FRY3	Guyane	Hydrogen	Battery technology	Sustainable packaging
FRY4	Réunion	Smart grids	Cryptography and distributed ledger technology	Biocides
HR03	Jadranska Hrvatska	Marine energy	Hydropower	Biocides
HR04	Kontinentalna Hrvatska	Marine energy	Hydropower	Drones
HU10	Közép-Magyarország	Cloud and edge computing	Cryptography and distributed ledger technology	Cybersecurity
HU21	Közép-Dunántúl	5G	Internet of things	Biocides
HU22	Nyugat-Dunántúl	Sustainable packaging	Recycling technologies	Bio fertilizers
HU23	Dél-Dunántúl	Biocides	Virtual Reality and Augmented Reality	Artificial intelligence
HU31	Észak-Magyarország	Robotics (autonomous)	Smart farming	Virtual Reality and Augmented Reality
HU32	Észak-Alföld	Biocides	Bio fertilizers	Geothermal energy
HU33	Dél-Alföld	5G	Cloud and edge computing	Drones
IE01	Border, Midland and Western	Virtual Reality and Augmented Reality	Artificial intelligence	Marine energy
IE02	Southern and Eastern	Cryptography and distributed ledger technology	Cybersecurity	Broadband
IS01	Höfuðborgarsvæði	Greenhouse gas capture	Drones	Bio fertilizers
IS02	Landsbyggð	Greenhouse gas capture	Bio fertilizers	Geothermal energy
ITC1	Piemonte	Bio fertilizers	Geothermal energy	Electric vehicles
ITC2	Valle d'Aosta/Vallée d'Aoste	5G	HVAC Systems	Smart grids
ITC3	Liguria	Hydropower	Marine energy	Wind energy
ITC4	Lombardia	Geothermal energy	Recycling technologies	Sustainable packaging
ITF1	Abruzzo	Biocides	Sustainable packaging	Bio fertilizers
ITF2	Molise	Robotics (autonomous)	Biocides	Virtual Reality and Augmented Reality
ITF3	Campania	Sustainable packaging	Marine energy	Cryptography and distributed ledger technology
ITF4	Puglia	Hydropower	Marine energy	Sustainable packaging
ITF5	Basilicata	Sustainable packaging	Biocides	Artificial intelligence
ITF6	Calabria	Hydropower	Marine energy	Biocides

NUTS-2		Top technological opportunities		
Code	Name	1st	2nd	3rd
ITG1	Sicilia	Cybersecurity	Cryptography and distributed ledger technology	Cloud and edge computing
ITG2	Sardegna	Hydropower	Marine energy	Biocides
ITH1	Provincia Autonoma di Bolzano/Bozen	Marine energy	Additive manufacturing (3D printing)	Sustainable packaging
ITH2	Provincia Autonoma di Trento	Hydropower	Marine energy	Geothermal energy
ITH3	Veneto	Geothermal energy	Heat pumps	Bio fertilizers
ITH4	Friuli-Venezia Giulia	Bio fertilizers	Waste management	Recycling technologies
ITH5	Emilia-Romagna	Robotics (autonomous)	Sustainable packaging	Marine energy
ITI1	Toscana	Robotics (autonomous)	Smart farming	Greenhouse gas capture
ITI2	Umbria	Biocides	Sustainable packaging	Robotics (autonomous)
ITI3	Marche	Biocides	HVAC Systems	Smart farming
ITI4	Lazio	Bio fertilizers	Cryptography and distributed ledger technology	Fuels from waste
LI00	Liechtenstein	Additive manufacturing (3D printing)	Semiconductors	Photonics
LT00	Lietuva	Drones	Bio fertilizers	Virtual Reality and Augmented Reality
LU00	Luxembourg	Sustainable packaging	Virtual Reality and Augmented Reality	Recycling technologies
LV00	Latvija	Greenhouse gas capture	Biofuels	Bio fertilizers
MT00	Malta	Hydropower	Cryptography and distributed ledger technology	Marine energy
NL11	Groningen	Biocides	Marine energy	Hydropower
NL12	Friesland (NL)	Sustainable packaging	Hydropower	Marine energy
NL13	Drenthe	Advanced Sustainable Materials	Bio fertilizers	Heat pumps
NL21	Overijssel	Greenhouse gas capture	Sustainable packaging	Recycling technologies
NL22	Gelderland	Biocides	Bio fertilizers	Sustainable packaging
NL23	Flevoland	Geothermal energy	Biocides	Sustainable packaging
NL31	Utrecht	Greenhouse gas capture	Bio fertilizers	Fuels from waste
NL32	Noord-Holland	Greenhouse gas capture	Fuels from waste	Wind energy
NL33	Zuid-Holland	Greenhouse gas capture	Fuels from waste	Wind energy
NL34	Zeeland	Bio fertilizers	Greenhouse gas capture	Recycling technologies
NL41	Noord-Brabant	Virtual Reality and Augmented Reality	Photonics	Artificial intelligence
NL42	Limburg (NL)	Fuels from waste	Greenhouse gas capture	Advanced Sustainable Materials
NO01	Oslo og Akershus	Marine energy	Geothermal energy	Hydropower
NO02	Hedmark og Oppland	Wind energy	Robotics (autonomous)	Additive manufacturing (3D printing)
NO03	Sør-Østlandet	Marine energy	Hydropower	Geothermal energy
NO04	Agder og Rogaland	Hydropower	Marine energy	Wind energy
NO05	Vestlandet	Marine energy	Hydropower	Greenhouse gas capture
NO06	Trøndelag	Hydropower	Wind energy	5G
NO07	Nord-Norge	Drones	Hydropower	Marine energy
PL11	Łódzkie	Biocides	Bio fertilizers	Sustainable packaging
PL12	Mazowieckie	Geothermal energy	Sustainable packaging	Bio fertilizers
PL21	Małopolskie	Cybersecurity	Cloud and edge computing	Cryptography and distributed ledger technology
PL22	Śląskie	Bio fertilizers	Heat pumps	Green buildings
PL31	Lubelskie	Greenhouse gas capture	Wind energy	Solar energy
PL32	Podkarpackie	Cloud and edge computing	5G	Cryptography and distributed ledger technology
PL33	Świętokrzyskie	Sustainable packaging	Hydrogen	Recycling technologies
PL34	Podlaskie	Biocides	Additive manufacturing (3D printing)	Advanced materials/nanomaterials

NUTS-2		Top technological opportunities		
Code	Name	1st	2nd	3rd
PL41	Wielkopolskie	5G	Cybersecurity	Cloud and edge computing
PL42	Zachodniopomorskie	Biocides	Photonics	Broadband
PL43	Lubuskie	Sustainable packaging	Additive manufacturing (3D printing)	Cybersecurity
PL51	Dolnośląskie	5G	Internet of things	Broadband
PL52	Opolskie	Greenhouse gas capture	Sustainable packaging	Green buildings
PL61	Kujawsko-Pomorskie	Biocides	Advanced materials/nanomaterials	Bio fertilizers
PL62	Warmińsko-Mazurskie	Bio fertilizers	Biocides	Sustainable packaging
PL63	Pomorskie	Cloud and edge computing	Cybersecurity	5G
PT11	Norte	Marine energy	Hydropower	Biocides
PT15	Algarve	Virtual Reality and Augmented Reality	Green buildings	HVAC Systems
PT16	Centro (PT)	Cybersecurity	Artificial intelligence	Cryptography and distributed ledger technology
PT17	Lisboa	Marine energy	Hydropower	Biocides
PT18	Alentejo	Sustainable packaging	Recycling technologies	Bio fertilizers
PT20	Região Autónoma dos Açores	Hydropower	Marine energy	Wind energy
PT30	Região Autónoma da Madeira	Cybersecurity	Cloud and edge computing	5G
RO11	Nord-Vest	Hydropower	Wind energy	Marine energy
RO12	Centru	Hydropower	Artificial intelligence	Marine energy
RO21	Nord-Est	Cloud and edge computing	Cybersecurity	Cryptography and distributed ledger technology
RO22	Sud-Est	Cloud and edge computing	Cybersecurity	Cryptography and distributed ledger technology
RO31	Sud - Muntenia	Marine energy	Smart grids	Wind energy
RO32	Bucureşti - Ilfov	Cryptography and distributed ledger technology	Cybersecurity	Cloud and edge computing
RO41	Sud-Vest Oltenia	Cryptography and distributed ledger technology	Cloud and edge computing	Cybersecurity
RO42	Vest	Virtual Reality and Augmented Reality	Artificial intelligence	Cybersecurity
SE11	Stockholm	5G	Internet of things	Broadband
SE12	Östra Mellansverige	5G	Internet of things	Drones
SE21	Småland med öarna	Heat pumps	Green buildings	HVAC Systems
SE22	Sydsverige	5G	Geothermal energy	Internet of things
SE23	Västsverige	5G	Internet of things	Broadband
SE31	Norra Mellansverige	5G	Sustainable packaging	Recycling technologies
SE32	Mellersta Norrland	Fuels from waste	Sustainable packaging	Recycling technologies
SE33	Övre Norrland	5G	Broadband	Internet of things
SI03	Zahodna Slovenija	Geothermal energy	Heat pumps	Hydropower
SI04	Vzhodna Slovenija	HVAC Systems	Heat pumps	Green buildings
SK01	Bratislavský kraj	Marine energy	Hydropower	Bio fertilizers
SK02	Západné Slovensko	Hydropower	HVAC Systems	Heat pumps
SK03	Stredné Slovensko	Bio fertilizers	Artificial intelligence	Fuels from waste
SK04	Východné Slovensko	Biocides	Bio fertilizers	Nuclear energy
UKC1	Tees Valley and Durham	Greenhouse gas capture	Advanced materials/nanomaterials	Hydrogen
UKC2	Northumberland and Tyne and Wear	Biocides	Battery technology	Solar energy
UKD1	Cumbria	Hydropower	Marine energy	Virtual Reality and Augmented Reality
UKD3	Greater Manchester	Drones	Greenhouse gas capture	Cryptography and distributed ledger technology
UKD4	Lancashire	Drones	Additive manufacturing (3D printing)	Robotics (autonomous)
UKD6	Cheshire	Biocides	Nuclear energy	Greenhouse gas capture
UKD7	Merseyside	Biocides	Sustainable packaging	Additive manufacturing (3D printing)
UKE1	East Yorkshire and Northern Lincolnshire	Biocides	Greenhouse gas capture	Bio fertilizers

NUTS-2		Top technological opportunities		
Code	Name	1st	2nd	3rd
UKE2	North Yorkshire	Greenhouse gas capture	Advanced materials/nanomaterials	Robotics (autonomous)
UKE3	South Yorkshire	Wind energy	Additive manufacturing (3D printing)	Sustainable packaging
UKE4	West Yorkshire	Biocides	Greenhouse gas capture	Water treatment
UKF1	Derbyshire and Nottinghamshire	Sustainable packaging	Nuclear energy	Hydropower
UKF2	Leicestershire, Rutland and Northamptonshire	Drones	Sustainable packaging	Water treatment
UKF3	Lincolnshire	Water treatment	Additive manufacturing (3D printing)	Efficient power & combustion
UKG1	Herefordshire, Worcestershire and Warwickshire	Bio fertilizers	Water treatment	Sustainable packaging
UKG2	Shropshire and Staffordshire	Additive manufacturing (3D printing)	Smart grids	Green buildings
UKG3	West Midlands	Electric vehicles	Autonomous mobility	Virtual Reality and Augmented Reality
UKH1	East Anglia	Cryptography and distributed ledger technology	Cybersecurity	Cloud and edge computing
UKH2	Bedfordshire and Hertfordshire	Biocides	Drones	Greenhouse gas capture
UKH3	Essex	HVAC Systems	Cryptography and distributed ledger technology	Broadband
UKI1	Inner London	Cryptography and distributed ledger technology	5G	Cybersecurity
UKI2	Outer London	Cryptography and distributed ledger technology	Cybersecurity	Cloud and edge computing
UKJ1	Berkshire, Buckinghamshire and Oxfordshire	Artificial intelligence	Advanced materials/nanomaterials	Virtual Reality and Augmented Reality
UKJ2	Surrey, East and West Sussex	Cryptography and distributed ledger technology	5G	Cybersecurity
UKJ3	Hampshire and Isle of Wight	5G	Cryptography and distributed ledger technology	Cybersecurity
UKJ4	Kent	Drones	Biocides	Virtual Reality and Augmented Reality
UKK1	Gloucestershire, Wiltshire and Bristol/Bath area	5G	Hydropower	Cloud and edge computing
UKK2	Dorset and Somerset	Drones	Hydropower	Cryptography and distributed ledger technology
UKK3	Cornwall and Isles of Scilly	Greenhouse gas capture	Marine energy	Hydropower
UKK4	Devon	Marine energy	Hydropower	Greenhouse gas capture
UKL1	West Wales and The Valleys	Marine energy	Hydropower	Wind energy
UKL2	East Wales	Cryptography and distributed ledger technology	Cybersecurity	Cloud and edge computing
UKM2	Eastern Scotland	Marine energy	Hydropower	Virtual Reality and Augmented Reality
UKM3	South Western Scotland	Hydropower	Marine energy	Water treatment
UKM5	North Eastern Scotland	Marine energy	Hydropower	Greenhouse gas capture
UKM6	Highlands and Islands	Hydropower	Marine energy	Biocides
UKN0	Northern Ireland	Artificial intelligence	Cybersecurity	Greenhouse gas capture

Notes: The *Top technological opportunities* refer to the technologies with the highest relatedness score in each region. Sources: OECD REGPAT, own elaboration.

Table A.7: Realised and potential for inter-regional linkages between European regions for digital technologies

NUTS-2 region	Realised inter-regional linkages					Untapped potential for linkages			
	Linkages	Share of cross-border linkages	Top partner regions			Average un-tapped potential score	Top potential partner regions		
			1st	2nd	3rd		1st	2nd	3rd
AT11	33	12%	AT13	AT22	AT12	41.73	DE21	DE30	CH04
AT12	291	33%	AT13	AT31	DEA2	43.11	HU10	CH04	UKJ3
AT13	592	61%	AT12	FI1B	DE21	42.38	UKJ3	PL21	HU33
AT21	127	79%	CZ02	SE11	DE21	43.25	DE21*	CH04	HU10
AT22	300	71%	SE11	AT13	AT31	42.39	HU10	DE30*	CZ01
AT31	223	65%	SE23	DE21	AT22	41.99	DE30	HU10	CZ01
AT32	46	46%	AT31	DE21	AT21	42.32	DE30	CH04	DE25*
AT33	80	74%	DE21	AT34	DE27	42.99	CH04	DE30	UKJ3
AT34	241	91%	CH05	CH03	CH04	43.75	DE21*	DE30	UKJ3
BE10	571	53%	BE24	ES30	FR42	42.44	UKJ3	UKK1	DE25
BE21	444	38%	BE24	BE23	BE22	44.21	UKK1	DE21	DE25
BE22	198	42%	BE21	BE24	AT31	42.96	DE21*	DE30	DE25
BE23	350	31%	BE25	BE21	BE24	43.46	UKK1	UKJ3	DE25
BE24	651	46%	BE21	BE10	BE23	42.12	UKK1*	DE25	UKI2
BE25	144	44%	BE23	DE25	FR10	44.07	UKK1	UKJ3	UKI1
BE31	234	36%	BE10	BE35	BE32	43.10	UKJ3	UKK1	DE30
BE32	175	39%	BE31	BE35	BE24	43.23	DE30	UKK1	DE25
BE33	204	50%	DEA2	BE10	BE24	42.97	DE21	UKJ3	UKK1
BE34	54	80%	LU00	FR41	DEB2	43.58	DE21	UKK1	DE30
BE35	143	15%	BE31	BE10	BE32	43.47	UKK1	DE25	DE30
BG31	3	33%	BG42	BG41	CH04	39.11	DE21	DE30	UKK1
BG32	0	0%				38.44	DE21	DE30	UKK1
BG33	0	0%				39.50	DE21	DE30	CH04
BG34	11	45%	BG41	UKJ4	CH04	39.33	DE21	DE30	DE25
BG41	25	64%	BG34	UKM2	CH04	39.27	DE21	DE25	HU10
BG42	6	50%	BG41	CH04	BG31	38.21	DE21	DE30	DE25
CH01	676	63%	CH02	FR71	CH04	42.20	DE25	ITC3	DE30
CH02	500	35%	CH01	CH03	CH04	42.76	UKK1	DE21*	ITC3
CH03	920	52%	CH04	DE13	CH02	42.57	UKK1	UKJ3*	HU10
CH04	971	44%	CH03	CH06	CH05	41.06	UKK1*	ITC3	FR82
CH05	291	49%	CH04	AT34	CH06	42.45	ITC3	DE30	FR82
CH06	349	36%	CH04	CH03	CH02	43.42	UKK1	UKJ3	FR82
CH07	107	72%	ITC4	CH01	CH03	43.17	DE21	DE25	UKK1
CY00	7	100%	SE11	UKK1	DK01	35.54	DE21	DE30	DE25
CZ01	149	30%	CZ05	CZ02	CZ04	43.11	DE30	DE40	DE21*
CZ02	205	68%	SE11	CZ01	AT21	43.89	DE21	DE30	DE25
CZ03	36	6%	CZ02	CZ01	CZ05	42.49	DE21	DE30	DE25
CZ04	33	15%	CZ01	CZ05	CZ07	42.79	DE21	DE30	DE25
CZ05	98	18%	CZ01	CZ02	CZ06	42.78	DE21	DE30	DE25
CZ06	63	49%	CZ01	CZ05	NL32	41.88	DE21	DE30	UKJ3
CZ07	50	26%	CZ08	CZ01	FR10	41.43	DE21*	DE30	HU10
CZ08	25	16%	CZ07	CZ03	CZ06	41.91	DE21*	DE30	PL21
DE11	2343	18%	DE14	DE12	DE21	40.43	FR82	UKI2	ITC3
DE12	1731	19%	DE11	DE71	DEB3	43.38	UKK1	FR82	ITC3
DE13	712	46%	CH03	DE11	DE14	42.36	UKJ3	UKK1	ITC3
DE14	1177	12%	DE11	DE12	DE21	43.20	CH04*	UKJ3	ITC3
DE21	4070	33%	DE25	DE27	ITG1	35.93	CZ02	PL21	PL22
DE22	853	6%	DE23	DE21	DE25	43.90	UKK1	CH04	CZ01
DE23	1359	6%	DE22	DE21	DE25	43.21	UKK1	CZ01	UKJ3
DE24	524	7%	DE25	DE21	DE23	43.52	DE30*	CH04	UKJ3
DE25	1731	17%	DE21	DE24	DE23	41.78	UKI2	CZ02	ITC3
DE26	658	10%	DE71	DE21	DE11	42.11	CH04	UKJ3	UKI1
DE27	832	12%	DE21	DE11	DE23	42.51	UKJ3	UKI1	ES30
DE30	1477	10%	DE40	DE21	DE25	40.65	UKK1	PL63	CZ02
DE40	678	6%	DE30	DE21	DE91	43.51	CZ01	HU10	PL63
DE50	120	0%	DE94	DE71	DE93	42.25	UKJ3	UKH1	DE30*
DE60	360	17%	DE21	DEF0	DE93	42.42	UKJ3	UKH1	PL63
DE71	1808	17%	DE12	DEB3	DE26	43.69	UKK1*	ITC3	HU10
DE72	207	12%	DE71	DE21	DE11	43.06	UKK1	UKJ3	UKI2
DE73	173	4%	DE71	DE26	DE91	42.60	UKJ3	DE25	UKI1
DE80	85	5%	DE25	DE21	DE30	41.48	UKJ3	UKK1	UKI2
DE91	574	8%	DE92	DE30	DE21	43.49	UKJ3	CH04*	DE25*
DE92	710	13%	DE91	DE11	DEA4	42.94	UKJ3	CH04	UKK1
DE93	172	6%	DE60	DE91	DE92	42.89	UKJ3	UKH1	CH04

NUTS-2 region	Realised inter-regional linkages					Untapped potential for linkages			
	Linkages	Share of cross-border linkages	Top partner regions			Average untapped potential score	Top potential partner regions		
			1st	2nd	3rd		1st	2nd	3rd
DE94	198	8%	DEA4	DE92	DE30	43.30	UKJ3	UKK1	CH04
DEA1	1114	27%	DEA2	DEA5	DEA3	41.61	UKJ3	UKK1	UKJ2
DEA2	1908	64%	SE11	DEA1	SE22	41.55	UKK1*	CH04*	UKJ2
DEA3	332	8%	DEA1	DEA5	DE71	43.59	UKJ3	UKK1	CH04
DEA4	409	6%	DE30	DEA5	DE92	43.89	UKJ3	UKK1	UKH1
DEA5	679	8%	DEA1	DE21	DEA4	42.79	UKJ3	UKH1	UKI1
DEB1	98	5%	DEA2	DE21	DE71	43.60	DE30	CH04	UKJ3
DEB2	72	39%	LU00	DEC0	DE21	43.22	DE30	CH04	UKJ3
DEB3	971	18%	DE71	DE12	DE11	41.99	UKK1	CH04*	FR10
DEC0	132	23%	DEB3	DEB2	LU00	42.97	UKK1	CH04	UKJ3
DED2	374	15%	DE21	DED4	DE14	41.73	HU10	CZ02	UKK1
DED4	227	21%	DED2	DE21	DEG0	42.74	CZ01	UKJ3	UKI2
DED5	250	7%	DE21	DEE0	DED2	41.77	UKK1	DE40	HU10
DEE0	276	5%	DE91	DEG0	DE30	43.13	UKK1	CH04	UKI2
DEF0	170	14%	DE60	DE21	DE92	42.15	UKJ3	UKK1	DE30*
DEG0	448	16%	DE21	DE11	DEE0	42.52	UKK1	UKJ3	PL41
DK01	232	59%	DK02	SE22	DK04	41.92	UKK1	DE21*	UKJ3
DK02	87	26%	DK01	DK04	UKJ2	42.68	DE30	DE21	UKK1
DK03	91	27%	DK04	DK01	DK05	42.03	DE30	DE21*	UKK1
DK04	265	45%	DK05	DK03	DK01	41.92	DE30*	UKJ3	SE23
DK05	439	81%	FI1B	DK04	DE21	43.22	DE30	CH04	UKJ3
EE00	25	100%	UKI1	FI1B	UKI2	37.69	DE30	DE21	DE25
EL30	193	88%	UKI2	DE71	NL33	40.07	DE25	CH04	UKK1
EL41	28	93%	ITC3	DE21	ITH3	39.32	DE30	CH04	UKJ3
EL42	0	0%				37.06	DE21	DE30	UKK1
EL43	6	83%	UKH1	UKJ3	CH01	37.18	DE21	DE30	UKK1
EL51	1	0%	EL30			39.23	DE21	DE30	CH04
EL52	36	36%	EL30	EL63	PT17	39.89	DE21	DE30	UKK1
EL53	0	0%				38.46	DE21	DE30	CH04
EL54	5	60%	FR10	EL43	EL63	38.64	DE21	DE30	UKK1
EL61	0	0%				38.87	DE21	DE30	UKK1
EL62	0	0%				38.40	DE21	DE30	CH04
EL63	18	28%	EL30	EL52	NL42	40.04	DE21	CH04	DE30
EL64	2	0%	EL30			37.80	DE21	DE30	UKK1
EL65	7	100%	ES30	SE11	CH01	38.61	DE21	EL30	DE30
ES11	41	63%	FR10	ES51	DED4	38.61	UKK1	DE21	UKJ3
ES12	30	70%	ES51	HU31	FR41	38.55	DE21	UKJ3	DE30
ES13	6	67%	DE12	ES30	ES11	39.11	DE21	UKJ3	DE30
ES21	79	62%	ES30	DEB3	SE11	39.58	UKJ3	DE30	UKK1
ES22	11	55%	UKG2	ES30	ES21	38.77	DE21	UKJ3	DE30
ES23	3	0%	ES51			39.65	DE21	UKK1	DE30
ES24	45	40%	ES30	ES51	ES61	40.21	UKK1	UKJ3	DE30
ES30	818	85%	SE11	SE23	SE22	37.87	DE25	PT16	DE27
ES41	26	12%	ES30	ES62	ES42	38.71	DE21	UKK1	DE30
ES42	50	46%	ES30	ES62	ES41	38.43	DE21	UKK1	DE30
ES43	2	0%	ES51	ES11		37.86	ES30	PT16	UKJ3
ES51	391	82%	DEA2	UKH3	DE12	39.41	DE30	UKJ3*	DE25
ES52	139	68%	ES30	DE21	SE12	39.02	UKK1	UKJ3	DE25
ES53	1	100%	DE71			39.63	DE21	CH04	UKJ3
ES61	114	67%	ES30	ES51	SE11	38.01	DE21	DE30	UKJ3
ES62	33	30%	ES42	ES30	ES41	38.07	DE21	UKK1	DE30
ES64	0	0%				37.30	DE21	UKK1	DE30
ES70	27	74%	ES51	FI1B	DE71	34.68	DE21	DE30	UKJ3
FI19	418	29%	FI1B	FI1D	FI1C	42.31	DE25	EE00	UKK1
FI1B	2968	71%	SE11	FI1D	SE12	38.93	UKJ3	NO06	EE00*
FI1C	559	62%	FI1B	SE11	SE22	41.18	DE30	DE25	UKJ3
FI1D	982	34%	FI1B	FI19	PL51	40.21	CH04	DE30	EE00
FI20	12	33%	FI1B	SE11	FI1D	40.58	DE30	DE21	FI19
FR10	1980	39%	FR71	FR52	FR24	38.69	UKK4	UKH2	CH05
FR21	44	23%	FR10	FR22	FR81	43.05	DE21	DE30	UKJ3
FR22	96	22%	FR10	FR21	DEA2	43.74	UKJ3	UKK1	DE30
FR23	59	19%	FR10	FR71	PT17	42.15	UKK1	UKI1	UKJ3*
FR24	179	7%	FR10	FR62	FR71	42.07	DE21	UKJ3	DE30
FR25	79	10%	FR10	FR71	FR82	42.41	UKK1	UKJ3	DE21
FR26	71	6%	FR71	FR10	FR61	42.06	DE21	UKK1	UKJ3
FR30	132	18%	FR10	FR71	FR82	43.61	UKK1	DE21	UKJ3
FR41	144	49%	FR10	LU00	BE34	43.54	DE21	CH04	DE30
FR42	310	77%	CH03	BE10	FR10	43.01	UKK1	DE30*	UKJ3*
FR43	61	43%	FR10	CH02	CH01	42.99	DE21	DE30	UKJ3

NUTS-2 region	Realised inter-regional linkages					Untapped potential for linkages			
	Linkages	Share of cross-border linkages	Top partner regions			Average un-tapped potential score	Top potential partner re-gions		
			1st	2nd	3rd		1st	2nd	3rd
FR51	162	20%	FR10	FR52	FR62	41.71	UKK1	UKJ3	DE21
FR52	364	27%	FR10	FR71	FR62	43.07	CH04	UKJ3*	UKI2
FR53	34	9%	FR10	FR71	FR52	40.49	DE21	UKJ3	DE30
FR61	213	24%	FR10	FR71	FR62	40.34	DE21	UKK1	DE30*
FR62	314	20%	FR10	FR71	FR61	41.14	CH04	UKJ3	DE30
FR63	22	18%	FR24	FR62	FR53	41.11	DE21	UKK1	UKJ3
FR71	875	34%	FR10	CH01	FR82	42.53	UKJ3	UKK1*	ITC3
FR72	59	10%	FR10	FR71	FR81	42.24	DE21	UKK1	CH04
FR81	160	29%	FR10	FR71	FR82	40.9	DE21	UKK1	DE30
FR82	542	51%	FR10	FR71	UKH1	41.26	ITC3	CH04	UKK1*
FR83	1	0%	FR71			41.27	DE21	ITC3	CH04
FRY1	2	0%	FR10			31.92	DE21	UKK1	DE30
FRY2	6	0%	FRY4	FR10		32.30	DE21	DE30	UKK1
FRY3	0	0%				29.62	DE21	DE30	UKK1
FRY4	11	0%	FR10	FRY2	FR30	29.63	DE21	DE30	CH04
HR03	1	0%	HR04			40.84	DE21	DE30	UKJ3
HR04	13	92%	DE26	ES30	AT31	40.61	DE21	DE30	DE25
HU10	659	61%	HU33	SE11	DE21	41.84	DE30	CH04	DE40
HU21	74	20%	HU10	HU23	DE21	42.94	DE30	CH04	DE40
HU22	136	42%	HU10	HU33	DEA2	43.46	DE21	CH04	DE30
HU23	34	9%	HU10	HU21	HU32	42.21	DE30	CH04	UKJ3
HU31	54	46%	HU10	DE11	DE25	41.50	DE30	PL21	CH04
HU32	30	0%	HU10	HU33	HU23	41.03	DE21	DE30	PL21
HU33	254	34%	HU10	HU22	SE11	42.08	DE30	CH04	DE25
IE01	123	52%	IE02	UKI1	SE11	40.76	UKK1	UKJ3	DE30
IE02	311	81%	IE01	UKI1	DEA2	40.41	UKK1*	UKD4	UKJ3*
IS01	4	25%	IS02	NO04		34.97	DE21	DE30	UKJ3
IS02	3	0%	IS01			36.07	DE21	UKK1	UKJ3
ITC1	205	30%	ITC4	ITI1	ITI4	41.34	CH04	DE30*	FR82*
ITC2	11	0%	ITC4	ITC1	ITF4	43.71	CH04	DE21	ITC3
ITC3	182	40%	ITI1	SE11	ITC4	41.54	FR82	DE25	CH04
ITC4	438	49%	ITH5	ITC1	ITH3	40.70	UKK1	DE21*	UKJ3
ITF1	62	53%	SE11	ITI4	SE12	41.63	DE21	UKK1	CH04
ITF2	4	25%	ITH5	FR10		39.99	DE21	ITF3	UKK1
ITF3	123	37%	ITI4	ITC4	SE11	41.19	DE30	DE25	DE21*
ITF4	87	9%	ITH5	ITC4	ITI4	39.43	DE21	DE30	HU10
ITF5	11	0%	ITF3	ITF4	ITI1	40.02	DE21	DE30	CH04
ITF6	5	20%	ITF3	ITI1	ITG1	38.81	DE21	DE30	UKK1
ITG1	263	94%	DE21	CH03	ITC1	41.13	DE30	DE25	UKK1
ITG2	17	6%	ITI1	ITC1	ITI2	39.12	DE21	DE30	DE25
ITH1	7	86%	DEA4	DE26	DE21	41.64	DE21*	DE30	CH04
ITH2	78	36%	ITH3	ITI4	ITH5	42.34	DE25	DE21*	CH04
ITH3	185	39%	ITC4	ITH2	DE21	42.86	DE25	UKK1	UKJ3
ITH4	38	24%	ITH3	ITH5	ITI1	42.47	DE21	DE30	CH04
ITH5	210	37%	ITC4	ITF4	ITC1	42.17	UKJ3	CH04	DE30*
ITI1	243	41%	ITC3	SE11	ITC1	42.07	UKJ3	UKK1	CH04*
ITI2	44	23%	ITI1	ITC3	BE22	41.32	DE21	DE30	CH04
ITI3	18	6%	ITC3	ITF4	ITI4	40.82	DE21	DE30	DE25
ITI4	276	50%	ITF3	ITC4	DK04	41.75	DE25	UKK1	DE30
LI00	15	100%	CH05	CH04	AT34	42.49	DE21	CH04*	DE25
LT00	15	100%	DE40	DE30	UKI1	38.70	DE21	DE25	UKK1
LU00	196	100%	CH04	AT34	CH03	44.39	DE25	DE21	DE30
LV00	5	100%	AT13	PL12	EE00	37.82	DE21	DE30	FI1B
MT00	21	100%	SE11	UKI1	DE21	39.02	DE30	CH04	DE25
NL11	20	75%	CH04	BE22	NL41	41.85	DE21	UKK1	DE30
NL12	12	83%	UKM2	FR71	BE10	41.78	DE21	DE30	UKJ3
NL13	1	0%	NL23			42.54	DE21	DE30	CH04
NL21	48	50%	NL22	NL32	DE94	42.04	DE21*	UKK1	UKJ3
NL22	99	39%	NL41	NL31	NL21	43.59	DE21	DE30	UKJ3
NL23	22	36%	NL32	BE24	FI1B	43.05	DE21	UKK1	DE30
NL31	148	43%	NL32	NL33	NL41	43.81	UKJ3	UKK1	DE30
NL32	261	49%	NL33	NL31	ITC4	42.57	UKJ3	UKK1	DE30
NL33	290	57%	NL32	NL31	EL30	42.04	UKK1	DE30	UKJ3
NL34	33	82%	NL41	ITC1	FR10	42.20	DE21	UKK1	DE30
NL41	273	62%	NL22	NL42	NL32	43.59	UKK1	UKJ3	DE21*
NL42	110	62%	NL41	UKJ1	DEA2	43.40	DE21	UKK1	DE30
NO01	167	41%	NO03	NO06	UKK1	40.24	DE30	SE23	DE21
NO02	19	16%	NO01	NO03	SE11	39.16	DE30	DE21	UKJ3
NO03	86	31%	NO01	NO06	SE11	40.33	DE30	DE21	UKJ3

NUTS-2 region	Realised inter-regional linkages					Untapped potential for linkages			
	Linkages	Share of cross-border linkages	Top partner regions			Average un-tapped potential score	Top potential partner re-gions		
			1st	2nd	3rd		1st	2nd	3rd
NO04	64	52%	NO05	NO01	NO06	40.89	DE30	DE21	UKJ3
NO05	87	47%	NO06	NO04	FI1C	39.85	DE30	DE21	UKJ3
NO06	100	37%	NO01	NO05	CH01	39.99	DE30	DE21	CH04
NO07	2	50%	NO01	DEA4		35.34	DE21	DE30	UKJ3
PL11	28	32%	PL22	DE30	PL12	41.91	DE21	DE25	DE30*
PL12	134	37%	PL63	IE02	PL22	40.99	DE30	DE25	HU10
PL21	170	36%	PL32	PL22	PL12	42.06	DE21	DE25	HU10
PL22	91	35%	PL21	PL12	PL32	42.42	DE21	DE30*	UKK1
PL31	36	14%	PL12	PL61	PL41	40.97	DE21*	DE30	UKK1
PL32	77	14%	PL21	PL22	PL12	41.95	DE30	DE21	DE25
PL33	12	0%	PL21	PL12	PL31	41.14	DE21	DE30	DE25
PL34	7	0%	PL12	PL62	PL21	39.58	DE21	DE30	DE25
PL41	106	48%	PL51	FI1D	FI1B	42.31	DE30	CH04	DE40
PL42	32	66%	PL12	SE31	DED2	42.98	DE30	DE21*	PL63
PL43	6	33%	PL41	DEB3	DE12	42.75	DE30	DE21	CH04
PL51	292	83%	FI1B	FI1D	DK05	44.39	DE30	CH04	DE25
PL52	6	0%	PL22	PL21		42.08	DE21	DE30	CH04
PL61	33	18%	PL63	PL12	PL21	41.34	DE21	DE30	UKK1
PL62	20	5%	PL63	PL41	PL12	40.13	DE30	DE21*	UKK1
PL63	101	51%	PL12	ES51	UKJ2	41.46	DE30	DE25	DE40
PT11	113	42%	PT16	DE11	PT17	38.56	UKK1	UKJ3	DE25
PT15	4	75%	SK01	ES51	PT16	37.07	DE21	ES30	UKJ3
PT16	78	14%	PT11	PT17	DE11	38.19	ES30	DE25	DE30
PT17	63	49%	PT11	PT16	PT18	38.30	UKK1	UKJ3	DE25
PT18	6	0%	PT17	PT16		37.73	DE21	ES30	DE30
PT20	0	0%				34.39	DE21	UKK1	DE30
PT30	0	0%				36.60	DE21	UKK1	CH04
RO11	13	8%	RO12	RO21	DE27	41.30	DE21	DE30	CH04
RO12	25	60%	RO11	IE01	DE21	40.55	DE30	CH04	UKJ3
RO21	21	10%	RO32	RO11	ITH5	41.25	DE21	DE30	CH04
RO22	32	9%	RO32	RO31	SE12	40.76	DE21	CH04	DE30
RO31	47	21%	RO32	RO22	UKD6	40.93	CH04	DE30	DE40
RO32	73	36%	RO31	RO22	RO21	40.55	DE21	DE25	CH04
RO41	4	25%	RO32	UKI1	RO31	40.68	DE21	CH04	DE30
RO42	16	94%	IE02	DE23	BE10	41.11	DE21	DE30	DE25
SE11	6215	32%	SE12	SE22	SE23	40.60	DE40	UKJ3	PL63
SE12	3023	19%	SE11	SE22	SE23	41.39	UKJ3	PL63	DE30*
SE21	277	20%	SE23	SE22	SE11	42.33	DE30	PL63	UKJ3
SE22	2770	28%	SE11	SE23	SE12	43.41	DE30*	CH04	PL63
SE23	1858	26%	SE11	SE22	SE12	44.17	CH04	NO01	UKH1
SE31	375	22%	SE11	SE12	SE23	41.74	NO01	CH04	DE30*
SE32	8	25%	SE11	SE33	AT12	38.37	DE30	UKK1	NO06
SE33	858	23%	SE11	SE12	SE22	40.28	DE30	CH04	UKK1
SI03	26	54%	SI04	AT22	UKI1	42.47	DE21	DE30	CH04
SI04	14	14%	SI03	UKJ1	DE21	42.21	DE21*	DE30	CH04
SK01	35	71%	SK03	BE10	AT13	42.20	DE30	HU10	CH04
SK02	34	82%	SK01	SK03	ES51	41.71	DE21	DE30	CH04
SK03	16	50%	SK01	CZ01	SK02	41.06	DE21	DE30	HU10
SK04	16	100%	PL63	FI1D	PL51	41.60	DE30	DE21	PL21
UKC1	59	31%	UKJ1	UKC2	UKM2	40.84	UKK1	DE21*	UKI2
UKC2	28	14%	UKC1	UKJ1	UKH3	40.72	UKK1	UKJ3	DE21*
UKD1	17	18%	UKJ1	ITH3	UKJ3	41.29	DE21	UKK1*	UKI1
UKD3	118	36%	BE24	UKD6	UKF1	41.42	UKK1*	DE30	DE25
UKD4	60	17%	UKJ2	PL63	UKK1	40.60	UKJ3	DE21	UKH1
UKD6	250	22%	UKI2	BE21	UKI1	44.33	UKK1	DE21	UKD4
UKD7	62	11%	UKI2	UKJ1	UKF1	41.90	UKK1	DE21	UKJ3*
UKE1	11	36%	DE71	UKF3	UKM3	41.00	UKK1	DE21	UKJ3
UKE2	89	27%	UKH3	UKI2	UKH1	41.36	UKJ3	DE21	DE30
UKE3	121	28%	UKH1	UKI1	UKF1	42.61	UKK1*	UKJ3*	UKD4
UKE4	41	17%	UKE2	UKH1	UKI1	42.13	UKK1	UKJ3	DE21
UKF1	107	30%	UKD3	UKD7	UKD6	42.32	UKK1*	UKJ3*	UKH1*
UKF2	111	38%	UKJ1	UKH1	UKH2	41.68	UKK1*	DE25	DE30
UKF3	40	50%	UKH1	DE21	NL21	41.92	UKK1	UKJ3	UKI2*
UKG1	115	21%	UKG3	UKJ1	UKJ2	41.60	UKI1	DE21	IE02
UKG2	96	29%	UKI1	UKK1	UKF1	41.78	UKJ3*	UKH1	UKK1*
UKG3	170	18%	UKI1	UKG1	UKH1	44.45	UKJ3*	DE30	UKJ2*
UKH1	624	38%	UKH2	UKI2	UKE3	41.37	UKD4	DE30	SE23
UKH2	356	13%	UKH1	UKJ2	UKI1	44.43	DE25	DE30*	CH04
UKH3	286	30%	UKJ2	ES51	UKH2	45.22	DE21	UKK1*	DE25

NUTS-2 region	Realised inter-regional linkages					Untapped potential for linkages			
	Linkages	Share of cross-border linkages	Top partner regions			Average un-tapped potential score	Top potential partner regions		
			1st	2nd	3rd		1st	2nd	3rd
UKI1	1040	35%	UKI2	UKJ2	UKJ1	43.45	DE27	DE25*	UKG1
UKI2	897	35%	UKI1	UKJ2	DE71	41.12	DE25	DE30	DE40
UKJ1	707	31%	UKI1	UKK1	UKJ3	40.89	UKD4	UKK4	SE23
UKJ2	620	25%	UKI1	UKI2	UKJ3	43.13	DE30	CH04	DE25
UKJ3	492	32%	UKJ2	UKJ1	SE22	41.47	DE30	DE25*	UKJ4
UKJ4	50	20%	UKI2	UKJ2	UKI1	42.50	UKJ3	DE21	DE25
UKK1	532	55%	UKJ1	FR10	DE21	41.12	DE30	IE02*	CH04*
UKK2	156	39%	UKD6	UKI1	UKJ3	41.77	DE25	DE30	UKJ2
UKK3	29	59%	UKJ3	UKE2	IE02	40.56	UKK1	DE21	UKI2
UKK4	41	41%	UKI1	FI1B	UKH1	41.81	UKK1*	DE21	UKJ3*
UKL1	41	12%	UKL2	UKI1	UKD7	41.05	UKK1*	UKH1	DE30
UKL2	74	30%	UKL1	UKJ1	UKD3	43.66	UKK1*	DE21	DE25
UKM2	193	52%	SE11	SE22	UKM3	41.48	DE21	UKI2	UKD4
UKM3	53	32%	UKM2	UKJ2	ITC4	40.68	UKK1	DE21	DE25
UKM5	18	33%	CH01	UKI1	UKH1	39.94	DE21	UKK1	DE30
UKM6	18	61%	CH01	UKM2	NO04	40.09	UKK1	DE21	UKJ3
UKN0	50	30%	UKJ1	IE02	UKI1	40.10	UKK1	DE21	DE30

Notes: Column *Linkages* denotes the number of inter-regional linkages with European NUTS-2 regions (including non-EU) recorded for the region in digital patents. *Share of cross-border linkages* denotes the share of cross-border linkages over total linkages in digital technologies for each region. The column *Top partner regions* lists the regions with the highest number of linkages with the respective region. The column *Average untapped potential score* denotes the average untapped potential score for each region across all partner regions and green technologies. The *Top potential partner regions* are based on the average untapped potential score for each region pair across all digital technologies. *Top potential partner regions* marked with an asterisk (*) already collaborate with the respective region. Sources: OECD REGPAT, own elaboration.

Table A.8: Realised and potential for inter-regional linkages between European regions for green technologies

NUTS-2 region	Realised inter-regional linkages					Untapped potential for linkages			
	Linkages	Share of cross-border linkages	Top partner regions			Average un-tapped potential score	Top potential partner re-gions		
			1st	2nd	3rd		1st	2nd	3rd
AT11	75	33%	AT12	AT13	AT22	39.05	ITC4	DEA3	SK01
AT12	300	34%	AT31	AT13	AT11	40.72	SK01	DEA3	ITC4
AT13	293	50%	AT12	AT22	AT31	43.09	SK01	ITC4	SK02
AT21	46	43%	AT22	AT31	DE71	39.47	ITC4	SI03	ITC1
AT22	230	53%	AT13	AT31	AT21	40.06	ITC4	ITC1	NL32
AT31	444	64%	AT12	SE23	FI1B	38.42	ITC4	FR81	DE80
AT32	75	61%	DE21	AT31	AT22	40.89	ITC4	DEA3	FR71
AT33	78	68%	AT22	DE21	DE27	40.18	ITC4	ITC1	DEA3
AT34	121	87%	CH05	DE14	DE21	41.38	ITC4	FR71	DEA3
BE10	339	48%	BE24	BE31	FR71	40.01	DEA5	DEA3*	UKG1
BE21	287	43%	BE24	BE23	BE22	40.53	ITC4	ITC1	DEA3
BE22	167	44%	BE21	AT31	BE24	39.34	DEA3	DEA5	UKK1
BE23	304	32%	BE25	BE21	BE24	39.83	ITC4	NL33	DEA5
BE24	390	39%	BE10	BE21	BE23	39.33	UKK1	DEA3	ITC1
BE25	116	18%	BE23	BE24	BE34	41.12	NL33	UKK1*	FR71
BE31	247	27%	BE32	BE10	BE35	41.03	DEA3	DEA5	ITC1
BE32	204	26%	BE31	BE35	BE24	41.63	DEA3	DEA5	UKK1
BE33	198	65%	DEA2	BE10	FR71	39.72	DEA3	ITC4	UKG1
BE34	48	63%	FR41	LU00	BE35	40.74	DEA3	DEA5	ITC4
BE35	160	17%	BE32	BE31	BE22	39.94	DEA3	UKK1	ITC4
BG31	20	15%	BG41	BG33	BG32	39.41	ITC4	DEA3	ITC1
BG32	18	0%	BG41	BG31	BG33	38.46	ITC4	DEA3	AT12
BG33	15	0%	BG41	BG32	BG31	38.67	ITC4	DEA3	ITC1
BG34	2	0%	BG41	BG32		39.86	ITC4	DEA3	FR71
BG41	32	38%	BG32	BG31	BG33	36.26	ITC4	DEA3	AT12
BG42	0	0%				37.57	ITC4	ITC1	DEA3
CH01	340	64%	CH02	FR71	CH04	45.99	ITC1*	DEA3*	DEA5
CH02	369	41%	CH01	CH04	CH03	44.85	DEA3	ITC1	ITC4*
CH03	572	54%	CH04	CH02	DE13	42.73	ITC4*	ITC1	ITH3
CH04	600	43%	CH03	CH06	CH02	42.71	DEA3	ITC1	DEA5
CH05	258	60%	CH04	AT34	CH03	41.89	ITC4*	FR71	ITC1
CH06	210	30%	CH04	CH03	CH02	43.35	ITC4	DEA3	ITC1
CH07	98	63%	ITC4	CH04	CH05	38.72	ITC1	DEA3	FR71
CY00	0	0%				34.26	ITC4	DEA3	FR71
CZ01	80	33%	CZ02	CZ05	CZ07	40.98	ITC4	DEA3	DEE0
CZ02	83	41%	CZ01	CZ05	FR10	42.57	ITC4	DEA3	DED4
CZ03	44	45%	CZ05	CZ01	CZ06	39.91	ITC4	DEA3	AT12
CZ04	29	52%	CZ01	CZ02	CZ03	41.36	DED4	ITC4	DEA3
CZ05	57	23%	CZ02	CZ01	CZ03	40.28	ITC4	DEA3	AT12
CZ06	39	54%	CZ03	CZ07	SK02	38.60	AT12	ITC4	DEE0
CZ07	51	37%	CZ08	CZ01	CZ02	38.44	ITC4	AT12	SK01
CZ08	18	28%	CZ07	DEA2	CZ02	40.67	ITC4	DEA3	SK01
DE11	1902	12%	DE12	DE14	DE21	43.97	ITC4*	ITH3	ITC1
DE12	1677	13%	DE11	DEB3	DE13	43.69	ITC4*	ITH4	ITH3*
DE13	752	31%	DE12	DE11	CH03	42.72	ITC4	ITC1	NL33
DE14	904	12%	DE11	DE27	DE12	44.52	ITC4*	NL33	NL32
DE21	1569	16%	DE25	DE27	DE22	42.56	ITC4*	ITC1	NL33
DE22	528	9%	DE21	DE23	DE25	44.30	ITC4	FR71	NL33
DE23	673	8%	DE22	DE25	DE21	43.57	ITC4	DEA3*	FR71
DE24	663	9%	DE25	DE23	DE26	41.60	ITC4	NL32	FR71
DE25	1146	7%	DE24	DE21	DE23	42.23	ITC4	ITC1	ITH3
DE26	818	8%	DE71	DE25	DE24	44.16	ITC4	NL33	ITC1
DE27	615	13%	DE21	DE14	DE11	42.59	ITC4	DEA3	FR71
DE30	712	12%	DE40	DEA1	DE91	42.23	ITC4	NO03	ITC1
DE40	283	9%	DE30	DE25	DE14	41.27	ITC4	DEA3	ITC1
DE50	137	2%	DE94	DE93	DE30	41.29	ITC4	FR71	DEA5*
DE60	391	19%	DEF0	DE93	DE23	43.20	ITC4	DEA3*	FR71
DE71	1361	14%	DE26	DEB3	DE12	43.44	UKG1	NL12	ITC1*
DE72	249	9%	DE71	DE26	DE73	40.10	ITC4	NL33	UKK1
DE73	216	5%	DE26	DEA5	DE72	39.71	ITC4	FR71	DE80
DE80	134	16%	DE25	DE30	DEF0	36.84	DEA3	ITC4	UKG1
DE91	448	10%	DE92	DEE0	DE30	42.25	ITC4	NL33	DEA3*
DE92	495	9%	DE91	DEA4	DE93	45.29	NL33	ITC4	NL12
DE93	307	10%	DE60	DE92	DE91	40.92	ITC4	DEA3*	NL32

NUTS-2 region	Realised inter-regional linkages					Untapped potential for linkages			
	Linkages	Share of cross-border linkages	Top partner regions			Average untapped potential score	Top potential partner regions		
			1st	2nd	3rd		1st	2nd	3rd
DE94	453	12%	DE50	DEA3	DE30	41.34	ITC4	NL12	FR71*
DEA1	1753	15%	DEA2	DEA5	DEA3	40.35	NL33	NL12	NL21
DEA2	1483	20%	DEA1	DEA3	DE71	44.59	NL33	NL21	NL12
DEA3	857	9%	DEA1	DEA5	DEA2	38.91	NL33	NL32	DEE0
DEA4	407	5%	DEA5	DE92	DEA3	42.70	ITC4	NL33	FR71
DEA5	1005	6%	DEA1	DEA3	DEA2	40.36	NL33	ITC4	NL12
DEB1	289	16%	DEA2	DEA1	FR71	42.33	ITC4	NL33	UKK1
DEB2	73	53%	LU00	DE71	FR41	41.10	ITC4	NL33	DEE0
DEB3	973	13%	DE12	DE71	DE11	41.29	ITC4	AT12	ITC3
DEC0	140	22%	DEA2	DEB3	DE11	42.97	ITC4	DEA3*	FR71
DED2	292	9%	DED4	DE11	DE21	40.21	ITC4	DEA3*	UKG1
DED4	198	12%	DED2	DE25	DE21	39.67	ITC4	ITC1	DE80
DED5	145	11%	DEE0	DED2	DE21	38.29	ITC4	DE93	DEA3*
DEE0	292	4%	DE91	DED5	DE30	37.94	ITC4	DEA3	NO01
DEF0	326	22%	DE60	DE93	DE25	41.27	ITC4	DEA3*	FR71
DEG0	258	7%	DEB3	DE11	DE71	44.33	ITC4	DE80	NL32
DK01	398	47%	DK02	DK04	SE22	39.01	DEA5	UKG1	ITC1
DK02	204	30%	DK01	SE22	DK04	38.54	ITC4	UKG1	DEA5
DK03	334	28%	DK04	DK05	DK01	39.31	DEA3	DEE0	DEA5
DK04	603	35%	DK03	DK05	DK01	41.12	ITC4	NO03*	DEE0
DK05	230	18%	DK04	DK03	DK01	42.14	ITC4	DEA3	NO03
EE00	10	100%	FI1B	NO03	NO01	37.19	DEA3	ITC4	DEA5
EL30	23	87%	UKD7	UKI1	DE30	36.22	DEA3	ITC4	FR71
EL41	8	100%	DE21	ITH3	ITC3	39.94	ITC4	DEA3	FR71
EL42	0	0%				39.39	ITC4	DEA3	FR71
EL43	4	100%	UKJ3			35.42	ITC4	FR71	ITC1
EL51	7	43%	EL52	SE23	SE22	38.91	ITC4	DEA3	ITH3
EL52	25	92%	SE11	SE12	NO01	36.27	ITC4	DEA3	FR71
EL53	2	0%	EL51	EL63		39.61	ITC4	DEA3	FR71
EL54	1	0%	EL63			39.79	ITC4	ITC1	DEA3
EL61	0	0%				40.37	ITC4	DEA3	FR71
EL62	0	0%				40.90	ITC4	DEA3	FR71
EL63	6	17%	EL30	EL53	EL51	37.07	ITC4	ITC1	FR71
EL64	0	0%				39.81	ITC4	DEA3	ITH3
EL65	1	0%	EL30			39.75	ITC4	FR71	ITH3
ES11	11	82%	FR10	DE30	DED4	35.89	UKK1	ITC4	FR71
ES12	10	40%	ES51	PT11	ES52	36.16	DEA3	ITC4	ITC1
ES13	12	67%	ES30	FR10	ES51	38.63	ITC4	DEA3	ITC1
ES21	57	54%	ES22	ES30	CH07	36.29	ITC1	ITC4*	FR62
ES22	67	34%	ES30	ES21	ES24	37.53	ITC4	FR71	DEA3
ES23	5	0%	ES21	ES12	ES22	39.49	ITC4	DEA3	FR71
ES24	35	29%	ES22	ES51	DE30	35.92	FR71	ITC4	ITC1
ES30	186	51%	ES52	ES61	ES22	37.73	DEA3	UKG1	UKK1
ES41	20	40%	ES30	FR10	NL34	36.31	UKK1	FR71	ITC4
ES42	23	30%	ES30	ES52	ES61	36.08	ITC4	FR71	DEA3
ES43	2	0%	ES41	ES30		39.09	ITC4	DEA3	FR71
ES51	152	72%	CH04	ES30	ES22	40.62	ITC1	ITC4*	FR81
ES52	114	61%	BE10	ES30	FR71	34.60	UKK1	DEA5	ITC1*
ES53	1	0%	ES30			37.75	ITC4	DEA3	FR71
ES61	75	48%	ES30	ES62	UKJ3	33.20	FR71	UKK1	DEA3
ES62	21	0%	ES61	ES52	ES30	34.83	ITC4	DEA5	UKK1
ES64	0	0%				39.84	ITC4	DEA3	FR71
ES70	19	37%	ES30	DE72	ES61	32.04	ITC4	ITC1	DEA5
FI19	111	24%	FI1B	FI1D	FI1C	37.65	NO01	DE80	DEA3
FI1B	263	49%	FI1C	FI19	AT31	38.20	NO01	AT12	DE93
FI1C	150	23%	FI1B	FI1D	FI19	34.10	NO01	UKK1	DEA3
FI1D	79	25%	FI1C	FI19	FI1B	37.05	NO01	FR71	ITC4
FI20	6	67%	SE11	ES52	FI1C	39.25	DEA3	NO03	NO01
FR10	1443	25%	FR71	FR22	FR51	43.29	UKG1	DE80	UKK1
FR21	99	5%	FR10	FR22	FR51	39.17	DEA3	DEA5	ITC4
FR22	262	21%	FR10	FR71	DEA2	41.28	NL33	ITC4	DEA3
FR23	130	5%	FR10	FR71	FR61	41.65	ITC4	DEA3	NL33
FR24	279	20%	FR10	FR71	FR52	38.9	DEA3	ITC4	DEA5
FR25	93	62%	BE31	FR10	BE32	38.24	UKK1*	DEA3	NL33
FR26	62	29%	FR10	DEA2	FR71	40.42	ITC4	UKK1	ITC1
FR30	171	20%	FR10	FR71	FR22	41.29	UKK1	ITC4	NL33
FR41	203	45%	FR10	FR71	LU00	40.34	ITC4	NL33	DEA5
FR42	289	67%	DE12	DE13	FR71	39.87	ITC4	DEA3	DEA5
FR43	130	52%	FR10	CH02	ITC4	43.33	DEA3	ITC4*	ITC3

NUTS-2 region	Realised inter-regional linkages					Untapped potential for linkages			
	Linkages	Share of cross-border linkages	Top partner regions			Average un-tapped potential score	Top potential partner re-gions		
			1st	2nd	3rd		1st	2nd	3rd
FR51	233	11%	FR10	FR52	FR71	38.62	UKK1	DEA3	DEA5
FR52	155	12%	FR71	FR10	FR51	42.19	UKK1	DEA3	ITC4*
FR53	117	11%	FR10	FR61	FR24	37.26	ITC4*	DEA5	DEA3
FR61	276	19%	FR71	FR10	FR53	36.33	ITC4	DEA5	UKK1
FR62	201	23%	FR10	FR71	FR51	41.18	UKK1	DEA3	ITC3
FR63	34	18%	FR10	FR24	FR82	39.56	ITC4	ITC1	DEA3
FR71	1155	40%	FR10	FR82	DEA1	38.96	ITC1	ITC3	DEA5*
FR72	76	16%	FR10	FR62	FR71	40.5	ITC4	ITC1	UKK1
FR81	235	9%	FR82	FR71	FR10	38.05	ITC4	ITC1	UKK1
FR82	368	29%	FR71	FR10	FR81	40.68	ITC1	DEA5	DEA3*
FR83	2	0%	FR10	FR22		41.59	ITC4	ITC1	FR71
FRY1	0	0%				32.56	ITC4	DEA3	FR71
FRY2	0	0%				33.36	ITC4	DEA3	FR71
FRY3	3	0%	FR61	FR10		33.06	ITC4	DEA3	ITC1
FRY4	3	0%	FR61	FR10		29.35	ITC4	DEA3	DEA5
HR03	7	71%	LU00	HR04	ITI1	42.14	ITC4	DEA3	ITC1
HR04	5	60%	HR03	FR71	DEA2	40.17	ITC4	DEA3	DEA5
HU10	119	62%	HU21	DE11	HU33	41.00	ITC4	FR71	DEA3
HU21	46	33%	HU10	HU22	HU33	39.09	ITC4	FR71	DEA3
HU22	35	40%	HU21	HU10	AT12	39.34	ITC4	AT12*	DEA3
HU23	3	0%	HU32	HU33		40.74	ITC4	FR71	DEA3
HU31	8	50%	HU10	DE11	DE12	40.70	ITC4	ITC1	DEA3
HU32	31	61%	HU10	FR25	UKG1	38.24	ITC4	DEA3	AT31
HU33	27	26%	HU10	HU21	HU22	38.48	ITC4	DEA3	DEA5
IE01	23	48%	IE02	UKJ4	UKI1	39.68	DEA3	UKK1	FR71
IE02	66	82%	IE01	UKM5	UKD6	40.21	DEA3	UKG1	UKK1
IS01	10	0%	IS02			34.59	ITC4	DEA3	DEA5
IS02	10	0%	IS01			34.19	DEA3	UKK1	DEA5
ITC1	272	24%	ITC4	ITC3	ITC2	38.04	FR71	DEA3	NL33
ITC2	36	47%	ITC1	FR10		43.30	ITC4	FR71	DEA3
ITC3	103	16%	ITC1	ITC4	ITF3	38.37	DEA3	FR71	DEA5
ITC4	449	42%	ITC1	ITH3	ITH5	36.84	DEE0	SI03	DEA3
ITF1	94	54%	PL21	NL33	CH03	38.21	DEA3	AT12	NL32
ITF2	10	20%	ITI4	ITF1	UKD7	39.32	ITC4*	FR71	ITF4
ITF3	66	23%	ITI4	ITC4	ITC3	38.51	DEA3	DEE0	DEA5
ITF4	76	24%	ITC4	ITF6	ITI4	37.20	DEA5	AT12	DEA3
ITF5	6	33%	ITC4	ITF3	FR42	37.73	ITF4	FR71	DEA3
ITF6	32	3%	ITF4	ITC4	ITI4	37.71	DEA3	DEA5	AT12
ITG1	26	19%	ITH5	ITI3	ITC4	38.90	DEA3	FR71	DEA5
ITG2	17	6%	ITC3	ITF3	ITC4	35.94	DEA3	ITC4*	FR71
ITH1	21	62%	AT33	ITH3	DEA4	38.41	ITC4	DEA3	ITC1
ITH2	56	41%	ITH5	ES30	ITH3	37.55	ITC4*	DEA3	FR71
ITH3	184	31%	ITC4	ITH4	ITC1	38.27	FR71	DEE0	DE93
ITH4	58	36%	ITH3	ITC4	ITH5	37.08	SI03	FR71	ITC1
ITH5	202	42%	ITC4	ITC1	ITH3	41.78	FR71	DEE0	DEA3*
ITI1	121	39%	ITC4	ITC1	ITH5	42.79	FR71	DEA3	FR81
ITI2	27	4%	ITC4	ITC1	ITI1	37.68	FR71	DEA3	DEE0
ITI3	32	3%	ITI4	ITH5	ITG1	39.16	DEA3	FR71	DEE0
ITI4	122	17%	ITH3	ITF3	ITF1	36.70	FR71	DEA3	DEA5
LI00	28	100%	CH05	AT34	DE21	43.09	ITC4	FR71	ITC1
LT00	13	100%	CH03	DE50	DED2	37.34	ITC4	DEA3	NO01
LU00	97	100%	FR41	DEB2	BE34	40.87	DEA3	NL33	ITC1
LV00	6	100%	ITC4	SI03	DK01	35.70	FR71	DEA3	NO01
MT00	2	100%	DE71	UKM6		37.45	ITC4	DEA3	ITC1
NL11	51	31%	NL13	NL22	NL41	38.31	DEA3	DEA5	DE94
NL12	49	27%	NL21	NL31	NL22	36.13	DEA3	DEA5	UKG1
NL13	29	21%	NL11	NL21	NL22	40.47	DEA3	DEA5	FR71
NL21	122	34%	NL22	NL12	NL31	37.58	DEA5	UKG1	DEA3*
NL22	238	34%	NL31	NL21	NL33	37.66	DEA5	DEA3*	UKK1
NL23	30	23%	NL22	NL11	NL33	40.87	DEA3	DEA5	NL32*
NL31	158	28%	NL22	NL33	NL41	39.49	DEA3	DEA5	FR71
NL32	179	47%	NL33	NL22	DK03	38.71	DEA3	DEA5	UKG1
NL33	284	49%	NL41	NL32	NL22	37.68	DEA3	DEA5	UKG1
NL34	51	69%	NL41	CH04	ES51	40.10	UKK1	NL33*	DEA5
NL41	252	46%	NL33	NL22	NL42	45.02	DEA3*	DEA5	NL21
NL42	170	65%	NL41	UKC1	NL33	40.15	DEA5	DEA3*	UKG1
NO01	179	33%	NO03	NO06	NO05	38.41	DEE0	DEA5	ITC1
NO02	13	15%	NO01	SE32	NO04	38.51	ITC4	DEA3	DEA5
NO03	105	24%	NO01	NO04	NO05	35.40	DEA5	DEA3	DEE0

NUTS-2 region	Realised inter-regional linkages					Untapped potential for linkages			
	Linkages	Share of cross-border linkages	Top partner regions			Average un-tapped potential score	Top potential partner re-gions		
			1st	2nd	3rd		1st	2nd	3rd
NO04	72	18%	NO05	NO03	NO01	38.66	ITC4	DEA3	DEE0
NO05	83	20%	NO04	NO01	NO06	37.88	DEA3	DEE0	FR71
NO06	64	23%	NO01	NO05	NO03	37.96	DEA3	ITC4	ITC1
NO07	8	13%	NO04	NO06	NO01	35.87	DEA3	ITC4	DEA5
PL11	33	6%	PL12	PL51	PL21	39.43	ITC4	DEA3	DEE0
PL12	103	29%	PL22	PL11	PL21	37.41	DEA3	DEA5	AT12
PL21	121	56%	CH03	PL22	PL12	39.22	ITC4	AT12	DEA3
PL22	64	39%	PL12	PL21	FR10	37.14	DEA3	DEE0	DEA5
PL31	16	25%	PL12	SE22	DE13	37.51	ITC4	DEA3	UKG1
PL32	6	33%	PL31	AT12	PL11	39.83	ITC4	DEA3	DEE0
PL33	21	19%	PL21	PL41	UKD7	38.96	ITC4	AT12	ITC1
PL34	9	11%	PL21	DEA3	PL42	40.16	ITC4	DEE0	PL12*
PL41	13	15%	PL33	PL42	PL12	38.8	ITC4	DEA3	DEA5
PL42	23	74%	DE12	DE13	DEA3	41.35	ITC4	DEE0	FR71
PL43	6	67%	FR71	DE12	PL42	41.33	ITC4	DEA3	DE80
PL51	43	30%	PL12	PL11	PL21	41.32	ITC4	DEA3	DEE0
PL52	6	33%	PL51	BE31	PL21	41.15	DEA3	ITC4	ITC1
PL61	11	18%	PL63	PL12	UKJ4	39.64	ITC4	DEA3	NO01
PL62	14	43%	PL12	UKJ4	PL61	38.93	ITC4	NO01	FR71
PL63	10	50%	PL61	UKJ2	UKD4	38.59	DEA3	ITC4	NO01
PT11	73	58%	PT16	PT17	DK04	35.99	DEA3	DEA5	FR71
PT15	7	0%	PT11	PT16		36.92	ITC4	FR71	DEA3
PT16	69	36%	PT17	PT11	PT18	37.27	DEA3	DEA5	DEE0
PT17	52	21%	PT16	PT18	PT11	35.94	ITC4	ITC1	UKK1
PT18	20	0%	PT17	PT16		37.03	ITC4	DEA3	FR71
PT20	7	14%	PT11	PT16	PT17	37.17	ITC4	DEA3	FR71
PT30	7	29%	PT17	UKG3	UKG2	37.57	ITC4	DEA3	FR71
RO11	10	10%	RO12	ES51		41.13	ITC4	DEA3	ITH3
RO12	11	18%	RO11	DE21	DE30	41.39	ITC4	DEA3	FR71
RO21	2	100%	AT13	ITC1		40.82	ITC4	DEA3	FR71
RO22	0	0%				40.50	ITC4	DEA3	FR71
RO31	5	40%	RO32	DE11	UKF1	39.82	ITC4	DEA3	ITH3
RO32	3	0%	RO31			40.15	ITC4	DEA3	ITC1
RO41	2	50%	DE25	RO42		41.13	ITC4	DEA3	ITH3
RO42	6	83%	DE23	DE71	RO41	41.54	ITC4	DEA3	FR71
SE11	304	34%	SE12	SE31	SE22	44.89	ITC4	DEA3	NO03*
SE12	241	34%	SE11	SE23	SE31	43.43	ITC4	NO03	FR71
SE21	105	45%	SE23	SE22	NL32	40.53	NO01	DEA3	NO03
SE22	268	57%	SE23	DK01	SE11	43.49	DEA3	DE80	DEE0
SE23	350	49%	SE22	SE31	SE21	42.31	DEA3	ITC4	NO03
SE31	134	19%	SE11	SE23	SE12	36.59	NO01*	DEE0	DEA3
SE32	40	43%	SE31	SE33	SE11	36.44	ITC4	DEA3	NO01*
SE33	27	19%	SE22	SE11	SE32	36.97	ITC4	NO01	DEA3
SI03	98	61%	SI04	DE11	AT22	37.19	ITC4	DEA3	ITH4
SI04	76	50%	SI03	DE11	UKG1	40.45	ITC4	DEA3	AT22
SK01	42	36%	SK03	SK02	SE32	37.22	AT12	ITC4	DEA3
SK02	38	68%	SK01	CZ06	CZ07	37.18	AT12	ITC4	DEA3
SK03	25	4%	SK01	SK02	SK04	38.85	ITC4	AT12	FR71
SK04	22	77%	HU10	HU32	SK02	39.25	ITC4	AT12	FR71
UKC1	80	34%	NL42	UKC2	UKJ1	37.93	UKG1	DEA3	ITC4
UKC2	74	61%	BE24	UKC1	DE25	39.28	DEA3	ITC4	UKG1
UKD1	6	67%	ITH3	AT34	NO03	39.76	DEA3	UKG1	ITC4
UKD3	149	47%	UKE3	DK04	CH04	41.84	UKK1	ITC1	DEA3
UKD4	56	25%	UKD6	UKD7	UKJ2	39.95	UKK1	UKG1	DEA3
UKD6	70	31%	UKD4	UKD3	IE02	40.25	DEA3	UKG1	DEA5
UKD7	43	35%	UKD4	UKJ1	EL30	40.68	UKK1*	UKG1	ITC4
UKE1	17	29%	UKE2	UKE4	NL22	40.24	UKK1	UKG1	DEA3
UKE2	45	33%	UKC1	UKE1	SE23	39.77	UKK1*	ITC4	DEA3
UKE3	92	51%	DK04	UKD3	DK01	39.59	ITC4	UKG1	UKK1
UKE4	36	19%	UKD6	UKF1	UKM2	39.75	UKK1	DEA3	ITC4
UKF1	93	30%	UKG2	UKJ3	UKM2	39.21	UKG1	DEA3	DEA5
UKF2	54	28%	UKG1	UKG3	UKL1	40.27	DEA3	ITC4	UKK1
UKF3	29	31%	UKH1	UKF1	BE24	41.91	ITC4	DEA3	UKG1
UKG1	199	55%	AT31	AT12	UKG3	38.68	UKK1*	NL32	UKL1
UKG2	70	49%	UKF1	UKG1	DE11	40.76	DEA3	ITC4	UKG1 *
UKG3	87	18%	UKG1	UKH1	UKJ1	42.83	ITC4	DEA3	NL33
UKH1	221	43%	UKJ1	UKI1	UKG3	44.31	NO03	NL32	NL12
UKH2	99	23%	UKJ1	UKH1	UKI1	41.59	DEA3	UKG1	DEA5

NUTS-2 region	Realised inter-regional linkages					Untapped potential for linkages			
	Linkages	Share of cross-border linkages	Top partner regions			Average un-tapped potential score	Top potential partner regions		
			1st	2nd	3rd		1st	2nd	3rd
UKH3	61	30%	UKH1	UKD3	UKI2	41.78	DEA3	NL33	ITC4
UKI1	161	25%	UKI2	UKJ1	UKJ2	45.57	DEA3	ITC4	ITC1
UKI2	140	21%	UKI1	UKJ2	UKJ3	44.58	DEA3	NL33	DEE0
UKJ1	308	37%	UKK1	CH03	UKH2	41.53	ITC4	ITC1	DEA3*
UKJ2	118	31%	UKI1	UKI2	UKJ1	43.41	DEA3	ITC4	NL32
UKJ3	223	48%	DK04	UKK1	DK03	42.53	ITC4	DEA3	FR71*
UKJ4	39	31%	UKH1	UKI2	UKD4	40.88	UKK1	ITC4	DEA3
UKK1	169	36%	UKJ3	UKJ1	UKJ2	39.63	DEA3	UKG1*	FR51
UKK2	56	25%	UKK1	UKJ3	UKH1	39.91	DEA3	FR71	ITC4
UKK3	30	20%	UKJ1	UKJ3	UKH2	35.73	UKG1	DEA5	DEA3
UKK4	19	16%	UKI2	UKH2	UKI1	38.98	DEA3	DEA5	UKK1*
UKL1	36	14%	UKL2	UKG3	UKF2	38.60	UKG1	ITC4	DEA3
UKL2	57	12%	UKJ1	UKG1	UKL1	42.61	DEA3	ITC4	UKK1*
UKM2	81	28%	UKM3	UKI1	UKF1	39.64	DEA3	DEA5	UKG1
UKM3	40	30%	UKM2	UKD3	DK04	38.31	DEA3	ITC4	DEE0
UKM5	14	57%	IE02	UKM2	PL63	39.50	DEA3	ITC4	DEA5
UKM6	13	54%	UKM2	FR10	MT00	39.34	ITC4	DEA3	DEA5
UKN0	20	30%	UKH1	UKC1	IE02	37.79	DEA3	UKK1	DEA5

Notes: Column *Linkages* denotes the number of inter-regional linkages with European NUTS-2 regions (including non-EU) recorded for the region in green patents. *Share of cross-border linkages* denotes the share of cross-border linkages over total linkages in green technologies for each region. The column *Top partner regions* lists the regions with the highest number of linkages with the respective region. The column *Average untapped potential score* denotes the average untapped potential score for each region across all partner regions and green technologies. The *Top potential partner regions* are based on the average untapped potential score for each region pair across all green technologies. *Top potential partner regions* marked with an asterisk (*) already collaborate with the respective region. Sources: OECD REGPAT, own elaboration.

Address | Contact

Bertelsmann Stiftung
Werderscher Markt 6
10117 Berlin
Germany
bertelsmann-stiftung.de

Dr. Thomas Schwab
Project Manager
Europe’s Future
thomas.schwab@bertelsmann-stiftung.de
www.bertelsmann-stiftung.de/europes-economy

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