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Abstract

Closing the prosperity gap between regions has always been a key political aspiration of the European Union – and cohesion policy is the primary means to achieve that goal. Europe is currently undergoing a digital and green transition that is drastically changing the way its economy works. How well prepared are regions to capitalise on the twin transition? And what impact will it have on regional cohesion in Europe? Our study finds that greening and digitalising the economy will likely widen the gap between rich and poor regions in Europe.

Keywords: EU, EU regions, regional development, digitalisation, green transition, cohesion

JEL Classifications: R11, O21

Contents

1 Introduction

Upward convergence – whereby member states make economic advances while the gap between countries and regions narrows – has always been a key political aspiration of the European Union. Similar economic circumstances and opportunities across regions are crucial for the Union's functioning and legitimacy. Therefore, the reduction of disparities and the pursuit of economic, social and territorial cohesion as enshrined in the Treaty on the Functioning of the European Union (Art. 174) are guiding principles for EU economic policy development.

Europe is undergoing a twin transition of digitalisation and decarbonisation that is drastically changing the way its economy works. The required adjustments vary greatly between activities and, subsequently, between European regions that differ in their economic structures and specialisations. Local assets such as internet accessibility, greenhouse gas intensity, and availability of high-skilled labour as well as social fabric play a key role in shaping economic structures. What is more, the activities in which a region specialises are indicative of its potential to benefit from the digital and green transition. Regions specialising in activities that design, produce or use digital and green solutions will strongly benefit from the twin transition. Regions with a pronounced reliance on agricultural activities need to adjust in a manner different than regions whose economies are dominated by knowledge-intensive services or high-technology intensive manufacturing industries.

The structural changes emanating from the twin transition could redraw Europe's economic landscape as we know it – and reshape economic cohesion in the EU. Regions prospering today may lose ground tomorrow, while lagging regions may leverage previously untapped potential and grow above expectations during this twin transition. As a result, existing disparities may intensify, vanish, or be complemented by new ones. In any case, fresh challenges for future EU cohesion are emerging which policymakers need to address to avoid the EU drifting further apart.

Increasing knowledge on the future development of EU cohesion and identifying regions that are particularly vulnerable in the transition are key to combat potentially centrifugal developments. So far, most studies focus on the historical development of regional economic growth and cohesion in the EU. Only a very few gaze into the future – and if they do, they focus on a few selected aspects, such as the transformation challenges of regions shaped by coal mining. As of now, no overarching analysis exists on the (likely) future of economic disparities across European regions.

This study aims to close this gap. It analyses the impact of the twin transition on the future economic development of European regions, shedding light on general growth potentials and the readiness for the digital and green transition in NUTS-2 regions across 27 EU member states. It provides novel evidence on how European economic prosperity and growth will be distributed in future and, subsequently, how economic cohesion across European regions will develop on the back of the twin transition. To analyse the potential regional growth patterns the study develops a scoring system to illustrate the regions' medium run growth potential in light of the digital and green transition. As this study is a foresight analysis, the results rely on several assumptions and come with a certain degree of uncertainty. Among others, we assume that national and subnational policy responses for the twin transition will be rather synchronised and are thus not altering the outlook for regions asymmetrically. While we consider the analysis to be a "thought experiment" rather than an exact forecasting exercise, each assessment of the potential future trends of European economic cohesion rests on a solid empirical and theoretical basis.

The analysis also evaluates the most likely effects that the digital and green transition will have on economic convergence in Europe. It addresses convergence across EU countries and regions as well as convergence within countries. Past developments have shown that EU cohesion was characterised by a narrowing of disparities across EU countries and regions, while regional disparities within countries tended to increase at the same time.

Our results show that the EU faces the danger of increasing disparities across NUTS-2 regions. While regions in Eastern Europe in particular have exhibited prolonged patterns of economic growth in recent decades, their outlook is less bright. Together with Southern European regions, which experienced stagnating economic development in the past, their prospects fall below those of their counterparts in Western and Northern Europe. The study shows that the twin transition will accentuate the gap between regions with good and bad economic prospects. We find evidence that the digital and green transition will increase disparities across European regions even further, as the necessary structural changes will be more easily carried out by already highly developed regions located mostly in the European core. In contrast, regions in the periphery, which already lag behind, will face additional burdens on improving their position. This translates into a threat of Europe drifting further apart and calls for action to gear future cohesion policy better to the fresh convergence challenges created by the twin transition.

The remainder of this study is structured as follows. In Section 2, we review the status quo of economic disparities across Europe, assess the potential for future economic growth and discuss the implications for future regional cohesion. Section 3 provides an overview on how the digital and green transitions are altering Europe’s economy. Based on these findings, we calculate for each region its readiness for the twin transition, combine it with the general potential for economic growth and derive implications for regional cohesion in the EU as a whole in Section 4. The final Section 5 summarises the findings and provides recommendations for EU cohesion policy.

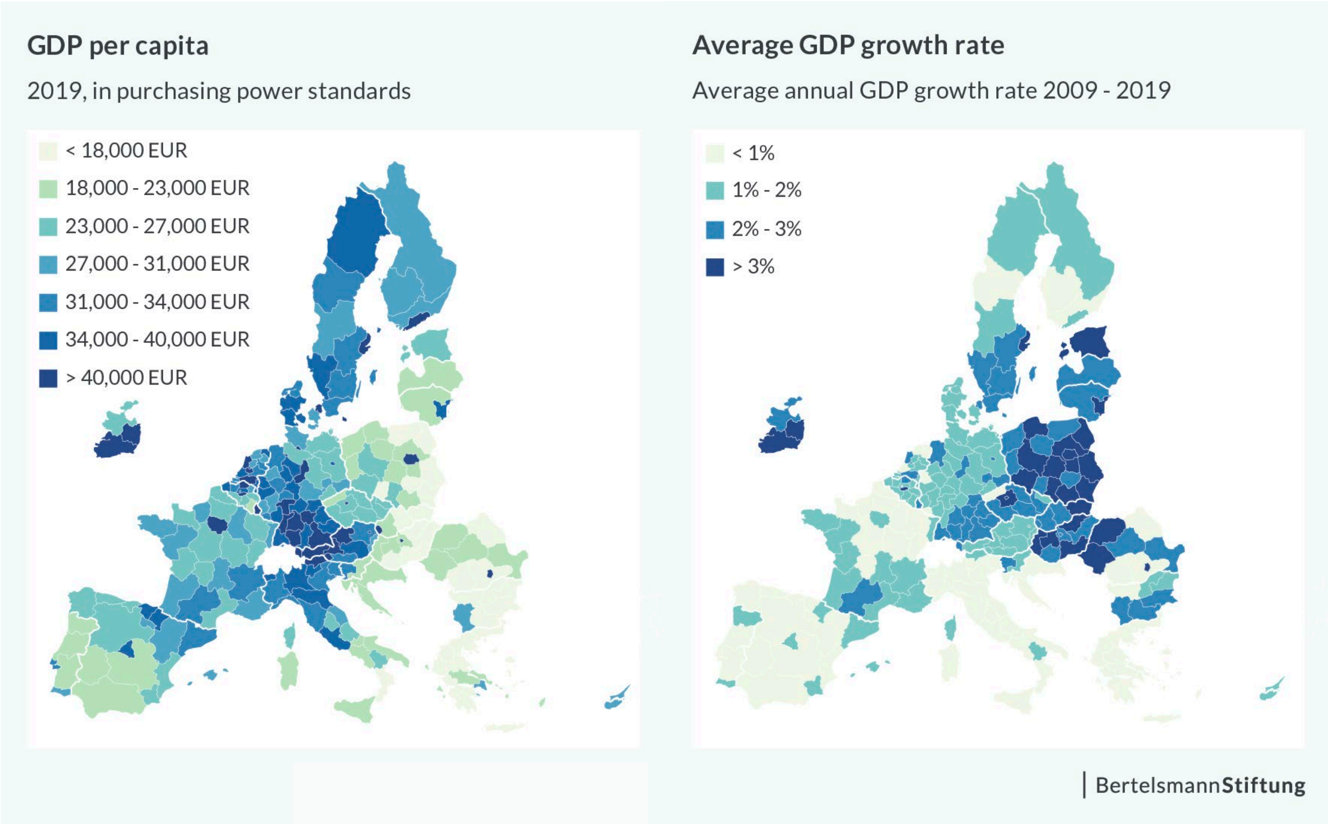
2 Economic cohesion across European regions

We start by analysing the current status of economic cohesion across EU NUTS-2 regions and recent developments in the past to illustrate the most important economic disparities today (Section 2.1). We then carry out an assessment of EU NUTS-2 regions' potential for future general economic growth (Section 2.2). Based on this assessment, we discuss the implications for the outlook on future economic cohesion – not yet factoring in the twin transition (Section 2.3).

2.1 Status quo of economic cohesion across European regions

European regions show substantial disparities in economic prosperity today, as Figure 1 (left panel) shows. The spread in purchasing power adjusted GDP per capita (2019) ranges from slightly over 10,000 Euro in some Bulgarian regions to more than 78,000 Euro in Luxembourg. This means that, while in some Bulgarian regions economic output is only 28 per cent of that of the EU-27 average (29,900 Euro in purchasing power standards per capita), in Luxembourg it is at 254 per cent well above the EU average.

Figure 1: Economic prosperity (left panel) and economic development (right panel) in EU NUTS-2 regions



Notes: The left panel shows GDP per capita (2019, measured in purchasing power standards). The right panel shows regions' average annual GDP growth rate in per cent from 2009 to 2019. Source: Eurostat and own calculations. Map: wiiw and Bertelsmann Stiftung.

Geographically, the regions with the lowest per capita income are located in the East, for example in Eastern Poland, Slovakia and Hungary, as well as in Romania, Bulgaria and large parts of Greece. A slightly higher GDP per capita, but still at the lower end of the EU regions, is recorded for Southern Italy, Spain and Portugal (outside Lisbon), and the Western parts of Poland, Slovakia and Hungary, as well as most regions in Czechia. Most regions in France as well as Eastern Germany have medium GDP per capita income levels, while the highest levels in the EU are recorded for Northern Italy, Austria, Western Germany, the Benelux countries and Ireland. Notably, capital city regions in all EU member states stand out as the most economically advanced (Figure 1, left panel). Indeed, they are mostly specialised in knowledge-intensive services and therefore high value-added activities (see Figure A1 in the Appendix). Likewise, regions in Western Germany and the Benelux countries known for their industrial focus exhibit high levels of GDP per capita, whereas other industrialised regions, for example in Northern France, have both lower GDP per capital levels and lower growth rates.

Over the last decade Europe experienced a phase of strong growth in Eastern European regions as Figure 1 (right panel) shows. The major driver behind this catching up has been the structural change within the economies from low value-added to higher value-added activities. The 8th Cohesion Report finds that the strong growth observed in Eastern Europe was also due to returns on infrastructure investment and low-cost advantages (European Commission, 2022a). These advantages are starting to disappear and are thus eroding the Eastern European regions' competitive advantages. To maintain the pace of growth going forward, these regions need to improve their skill endowments, innovation activities and institutions.

In contrast, many of the Southern European regions – particularly in Greece, but also Southern Italy, Spain and Portugal – never fully recovered from the 2008/2009 economic and financial crisis and have thus recorded low to very low economic growth rates over the last decade. The 8th Cohesion Report suggests that those regions fell into a so-called "development trap" that can only be exited with strong public sector reforms, skills upgrading and enhanced innovation potential (European Commission, 2022a).

2.2 Potential for economic growth in European regions

In this subsection we analyse the general growth potential of EU NUTS-2 regions. To determine the economic potential for European regions going forward, we assess five key factors of economic growth: human capital, innovation, investment, institutions, and infrastructure. We identified these five key factors in our econometric analysis (see Section A3 in the Appendix) and these are commonly reported by the large body of literature on regional growth as the most stable long-run determinants of regional growth.

The first key factor is high-skilled employment as skills play a fundamental role in the development and uptake of new technologies and production methods.[1]

The second key factor is institutional quality as it has been shown empirically that high institutional quality is strongly correlated with good economic performance (Charron et al., 2012).

The third key factor is infrastructure quality, though the impact of infrastructure on regional growth is disputed (Elburz et al., 2017). Multimodal transport accessibility plays a key role in regional growth, following the new economic geography theory underlining the importance of intraregional and interregional (cross-border) forces of agglomeration (Fujita and Thisse, 1996). There are potentially short-run negative effects, but long-run positive effects. In any case, our infrastructure measure is also a measure for the regions' market potential which, according to the new economic geography literature, is a key determinant of economic development.

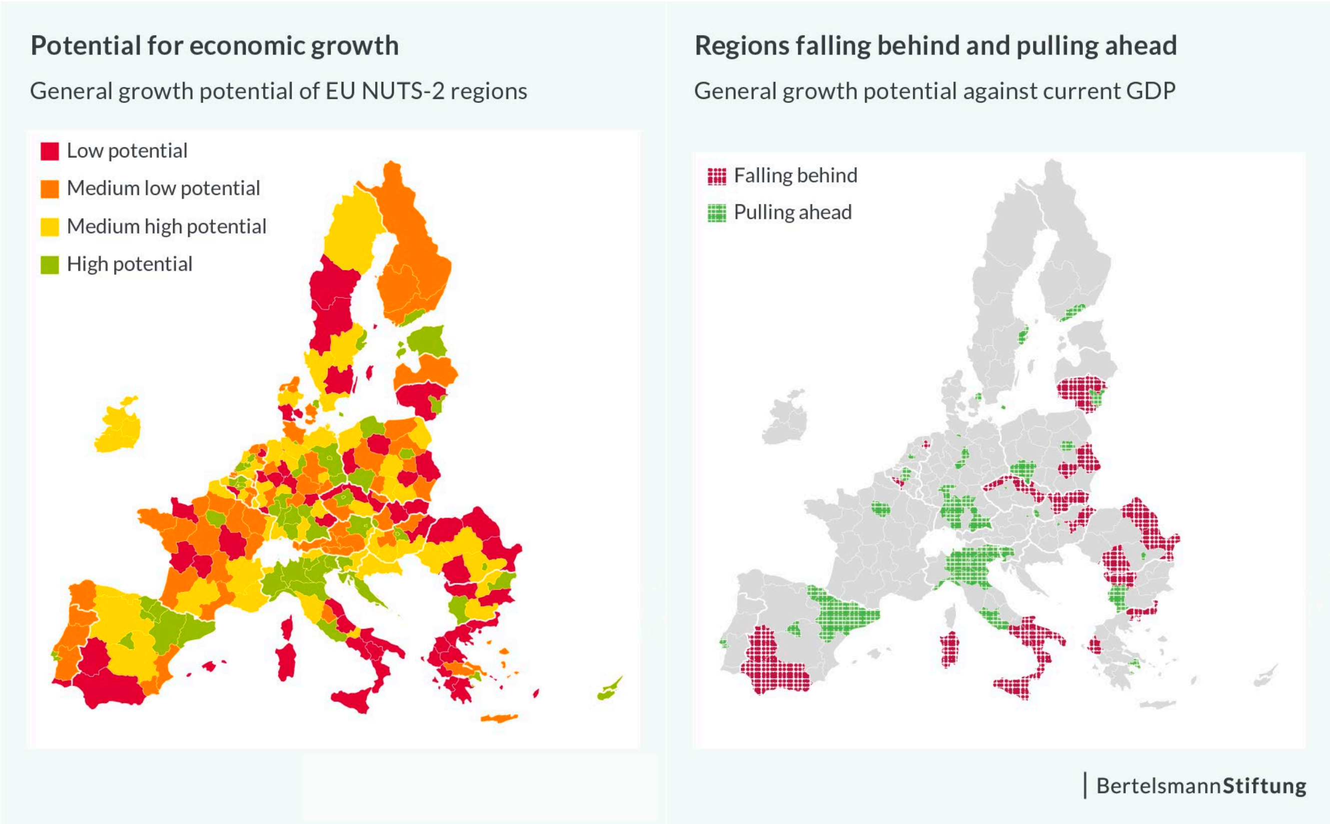
The fourth key factor is investment. On the supply side, it provides the capital necessary for production, while it is also a major contributor to effective demand.

[1] Demographic change including migration may alter the availability of high-skilled employment in regions (Petersen and Steiner, 2019). Due to substantial uncertainty for regional effects, we assume for the scope of this study a homogeneous development across all regions neglecting region-specific differentiations.

The fifth and final key factor is innovation, which is one of the most reliable growth predictors and describes the regions' potential to develop and use new and higher value-added technologies and methods. Innovation is a "key source of competitive advantage for territories and regions" (Crescenzi and Rodríguez-Pose, 2011) mainly via improving regional productivity and technological potential.

The key factors education and institutional quality determine the "absorptive capacity" of regions to make best use of investment (key factor four) for their socio-economic development (see, for example, Becker et al., 2013; Charron et al., 2012).

Figure 2: General growth potential for EU NUTS-2 regions (left panel) and regions falling behind and pulling ahead in economic prosperity (right panel)



Notes: The left panel shows the joint score of the five key factors for economic growth (high-skilled employment, institutional quality, infrastructure, investment and innovation), with regions grouped into four categories according to their growth potential. The scoring procedure is described in Section A3 in the Appendix. The right panel shows regions that are likely to fall behind (red) or pull ahead (green) in their economic development, which is determined by their correlation of general growth potential and current levels of GDP per capita. Source: Eurostat and own calculations. Map: wiiw and Bertelsmann Stiftung.

For each EU NUTS-2 region a joint score based on the corresponding values for each of the five key factors is calculated (see Section A3 in the Appendix for methodological details). The regions are grouped by their growth potential within four traffic-light categories, with red indicating the regions with the worst potential for economic growth and green those with the best growth potential. Regions marked in orange and yellow exhibit medium-low and medium-high potential, respectively. The results are illustrated in the left panel of Figure 2.

In geographical terms, regions more likely to follow an underlying upward development trend correspond to densely populated metropolitan regions in Europe. Regions more likely to face difficulties in their economic development are located in Southern Europe, in particular Southern Spain, Southern Italy and Greece, as well as at the EU's Eastern borders. In Western Europe, regions with medium-high and high growth potential are mostly located next to each other, pointing to growth potential spill-overs.

In terms of sectoral specialisation (see Section A1 in the Appendix for the classification of regions), regions specialising in knowledge-intensive services are best placed to experience future growth, ceteris paribus. These are often large metropolitan regions, which tend to have the highest innovation potential paired with a high-skilled labour force, adequate investments, and high levels of firm dynamics. What is more, regions specialising in high-technology intensive manufacturing tend to have a better potential for economic growth than other regions (except knowledge-intensive services regions). This is thanks to the presence of highly productive firms supported by a high-skilled labour force and above average innovation systems (see Figure A2 in the Appendix).

By contrast, regions specialising in low-tech intensive manufacturing industries have a comparatively lower growth potential. The lowest potential for economic growth is attributed to agricultural regions. They are mostly geographically remote (i.e. distant from markets), while they also lack important agglomeration economies, particularly relevant for innovation activities or participation in (global) value chains. Likewise, in many cases agricultural regions' skills endowment is inferior to those of other, more urban or industrialised regions.

2.3 Implications for future cohesion across European regions

The right panel of Figure 2 matches the EU regions' GDP per capita levels in 2019 with their future economic growth potential. Regions which show both high current GDP per capita levels and high growth potentials (marked in green) are pulling ahead in their economic development, whereas regions with low GDP per capita levels and low potential for economic growth (marked in red) will fall behind even more.

Regions in Greece, Southern Italy, Spain and Portugal which exhibited weak economic development in the past are among those with low growth potential. This will increase the spread between these regions and already highly prospering regions in Southern Germany and Northern Italy set to grow even more. The result will likely be increasing regional disparities across EU NUTS-2 regions in the medium to long run.

The suggested slowdown of growth in Eastern European regions is particularly worrisome. Regions in Poland, Romania, Slovakia and Czechia which experienced a prolonged phase of high economic growth exhibit low potential for future economic growth. This may be a first sign that many of the respective regions are in danger of falling into a development trap, where they remain stuck at income levels below the EU average. If so, this may not only call a halt to their catch-up process but widen the disparities even further. This points to a future slowdown or even a stop in convergence.

Our findings also point to increasing disparities within countries, in particular in Spain and Italy. The traditional gap in Italy between the lower income Mezzogiorno and the high-income Northern regions, including among others Lombardia, Veneto or Emilia-Romagna, is likely to grow further. Similarly in Spain, the Southern regions of Extremadura and Andalucía are likely to fall behind, while the already richer Northern and Western regions including País Vasco, Aragón or Cataluña are likely to pull ahead in terms of growth, intensifying the economic divide.

Therefore, even without the twin transition, we expect an increase in disparities in the EU, both between countries and regions as well as within countries. As a consequence, Europe may well (re-)enter a phase of different speeds of economic development and renewed divergence.

3 How the twin transition reshapes European regional economies

In the following, we provide a short overview on how the digital and green transition may affect regional economic growth. We also discuss characteristics and patterns of specialisation that determine the readiness of European regions for that transition.

3.1 Digital transition: New opportunities for regions with skilled labour and infrastructure

Digitalisation is defined as the "broad adoption of digital technology in homes, businesses and the society as a whole" (Alm et al., 2016). The process of digitalisation is expected to generate economic benefits in forms of more efficient and productive ways to generate value-added across economic sectors, thereby stimulating growth and job creation.

To this end, concrete goals have been set at the European level. For digitalisation, the Proposal for a Decision of the European Parliament and of the Council establishing the 2030 Policy Programme "Path to the Digital Decade" and the accompanying EU Staff Working Document (European Commission, 2021a, 2021b) set the following targets for the digital transformation of companies. By 2030:

- at least 75 per cent of enterprises in the EU should have adopted cloud computing services, mass data processing (Big Data) or artificial intelligence;
- more than 90 per cent of the Union's small and medium-sized enterprises should achieve at least basic digital intensity (adoption of digital technologies like websites, e-commerce, cloud computing, big data or internet access for employees);
- the EU should achieve a doubling of "unicorns", that is start-up companies with a valuation of 1 billion Euro or more, through the expansion of innovative scale-ups in the pipeline and improved access to finance.

Through its Digital Agenda, the EU intends to become "digitally sovereign in an open and interconnected world and to pursue digital policies that empower people and businesses to seize a human-centred, sustainable, and more prosperous digital future" (European Commission, 2021a).

It is expected that the digital transition significantly alters existing business models by introducing ground-breaking technologies and processes such as artificial intelligence, data analytics, robotics and the Internet of Things (European Commission, 2022b). At the same time, digitalisation comes with new skills requirements and calls for policies that strengthen foundation skills, promote lifelong learning and reinforce the link between education, training and the world of work (Morandini et al., 2020). But critically, the digital transition requires wide-ranging connectivity for people and businesses to access fast and reliable internet, supported by appropriate infrastructure. Here, the EU displays serious disparities: while more than 90 per cent of households have fixed broadband connection in the Netherlands, Cyprus and Luxemburg, less than two thirds are connected in Finland, Bulgaria, Latvia, Italy and Romania. The picture is more homogenous for businesses, although the proportion of enterprises with fixed broadband connection ranges between 81 per cent in Hungary to 100 per cent in Denmark (European Commission, 2021c).

Digitalisation can increase productivity, create new employment, and improve society's well-being by opening up new ways of working, learning, interacting and accessing public services such as healthcare. However, individuals and regions may not benefit equally from digitalisation. Indeed, digitalisation has stronger economic effects in more developed regions than in less developed ones, as the latter are more digitally constrained due to the concurrent requirement to switch from labour-intensive to more capital-intensive technologies. In those regions more than in others, digitalisation needs to be accompanied by an upskilling of the labour force to avoid labour market supply and demand mismatches, considerable investment in ICT infrastructure, and high-quality governance and policymaking to pave the way for an effective policy framework that is usually not available immediately.

Similarly, the regions' sectoral specialisation as well as their production technologies are further key factors determining their capacity to reap the benefits of digitalisation. Digitalisation prompts sectors to introduce more complex production methods, which may go hand in hand with a higher demand for high-skilled workers or the substitution of labour by machines within firms or industries. A recent study conducted for the European Commission reveals that "without proactive convergence measures, the effects of digital innovation would likely be distributed unevenly between member states, due to their industries' varying readiness to adopt disruptive technologies, and to supply it domestically" (European Commission, 2020a). This holds also for regions within EU member states, with regions relying on high-technology industries or knowledge-intensive services best placed to enjoy the benefits of digitalisation.

In terms of economic development, digitalisation means a potentially higher enterprise churn rate, because innovative new companies enter the market as others drop out. A similar observation is made for labour, as "old" jobs are lost while new jobs with different qualification profiles are created. From a regional point of view, it is noteworthy that firm and job creation and losses may not occur in the same region or, if in the same region, in equal numbers. Indeed, companies and jobs may well be lost in regions different from those where new ones are created, thereby deepening disparities between EU regions and countries. The adaptability of labour markets as well as their performance in terms of productivity and efficiency are thus key factors for a successful digital transition.

3.2 Green transition: Regions differ in their effort needed to achieve climate neutrality

The EU has the ambitious goal to "increase the greenhouse gas emissions reduction target for 2030 to 55 per cent" with the aim of transforming the EU into a climate-neutral economy by 2050 (European Commission, 2020b). Although the greenhouse gas emissions in the EU have been decreasing in the last decade, there is substantial variation at the national and regional level. This implies that for certain member states and regions there is a long way to go to reach those 2030 and 2050 goals. The European Commission has therefore proposed a range of initiatives, laws, financial resources and other instruments under the European Green Deal that address emission reductions in all key economic sectors, including agriculture, energy, transport, and industry. In total, 600 billion Euro from the #NextGenerationEU Recovery Plan and the EU's seven-year budget (multiannual financial framework) are expected to finance the delivery of the European Green Deal. Based on these steps, local and national policymakers will introduce more extensive measures to reduce emissions and end the reliance on fossil fuels in the coming years. Given the regions' differences in terms of energy and greenhouse gas intensity, sectoral specialisation, mobility patterns and housing stocks, the impacts of the green transition are expected to differ greatly across the EU.

Some studies suggest that the green transition may come at the cost of economic growth, particularly for the more energy and greenhouse gas intensive regions. Pirlogea and Cicea (2012) studied the link between energy consumption and economic development in the EU from 1990 to 2010 and found evidence suggesting greater energy consumption contributes to economic growth – but not for all member states. However, Topolewski (2021) points to a causal relation from economic growth to energy consumption in his findings. Thus, the need to reduce energy consumption and greenhouse gas emissions may pose a dilemma of choice between economic growth and green transition.

The most relevant sectors for reducing greenhouse gas emissions are energy industries, that is public electricity and heating plus petroleum refining. They account for 24 per cent of all EU emissions in 2019, followed by the transport sector (22 per cent) and buildings and manufacturing industries (both around 11 per cent). Together, these four sectors emit around 70 per cent of all EU greenhouse gases (European Commission, 2022c).

Hence, the green transition is a particular challenge for regions specialised in carbon-intensive industries such as coal mining, fossil fuel production, steel, basic chemicals (ethylene and ammonia) or cement. Those sectors are the most energy intensive and will therefore be forced to undergo the most dramatic changes to become carbon neutral, either through the introduction of alternative energy sources or new production technologies. Both of these will reduce fossil energy demand and, as a consequence, greenhouse gas emissions. Carbon capture, use and storage technologies could also mitigate emissions. One of the key problems for economic growth is that these changes require investment in new, greenhouse gas reducing capital stock without necessarily a concomitant rise in potential output. Thus, these industries will incur significant costs which – should these environmental investments crowd out others – will have few if any positive effects on economic growth.

Furthermore, the green transition will represent a disproportionate burden for less developed regions when it comes to the transportation sector – the shift to environmentally friendly forms of transport – and increasing energy efficiency in the housing sector. First, the transport and housing sectors of less developed regions are on average more energy intensive than those of more developed regions. Thus, replacement and renovation requirements emerge as stricter conditions for the former. Second, their capacity to invest in greenhouse gas reducing technologies is lower compared to other regions. As a consequence, these regions may need to invest a higher share of their GDP in the green transition to reach similar goals as their more developed peers. Where investment is, to some extent, crowded out, this also means that comparatively fewer funds will be available for other productive investments. This reduces their medium to long-run growth potential and their prospects of catching up with more developed regions.

The European Commission (2020c) estimates that at the aggregate level the impact of climate and energy policy on real GDP is expected to be modest but at the same time ambiguous, with models showing both positive and negative growth outcomes. There is, though, substantial variation between industry sectors. The output of energy intensive sectors is likely to decrease more. Depending on the costs of renewable energy, manufacturing sectors exposed to global competition, and the regions specialised therein, may also suffer from the green transition (if world competitors operate with lower energy prices using fewer renewables).

4 Assessing the impact of the twin transition on European cohesion

In this section, we assess how the digital and green transition may alter the outlook on future economic development for EU NUTS-2 regions. We analyse which regions are likely to improve or deteriorate their position determined in Section 2.2 in the light of the digital and twin transition. This is done by assessing the readiness of regions for the digital and green transition using selected key factors. High levels of readiness increase the potential for economic growth while low levels dampen the potential. By adding up the general potential for economic growth and the levels of readiness of regions, we then analyse the future landscape of economic growth and prosperity in Europe and its implications for economic cohesion.

4.1 Deviations in economic growth potential caused by the digital transition

To analyse the impact of the digital transition on the regions' growth potential, we assess their readiness using five key factors. The selection of the key factors follows from the analysis carried out in Section 3.1. Based on the current level of these key factors we assess the readiness for the digital transition for each NUTS-2 region. Regions with a high (low) level of digital readiness are expected to have a higher (lower) potential for economic growth than we assessed in Section 2.2.

The first key factor is labour productivity, which is an additional proxy for the regions' technological readiness. The hypothesis is that labour productivity at least partly depends on the production technology employed. Thus, higher productivity is associated with a higher technological level, which in turn implies a more intensive use of modern technologies.

The second key factor is internet accessibility. In the Commission's Regional Competitiveness Index this indicator is used as a variable to measure technological readiness. It aims at estimating how far households and enterprises are using and adopting existing digital technologies.

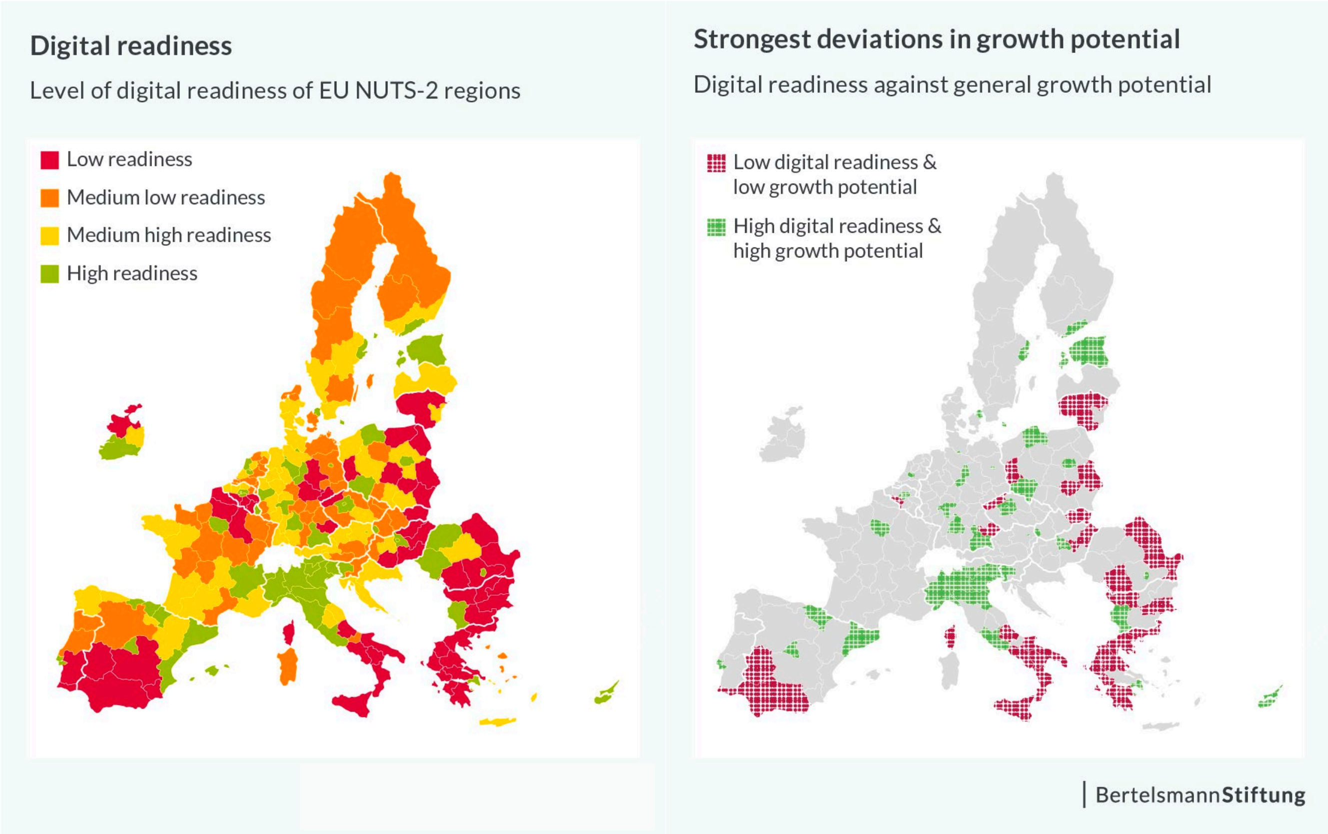
The third key factor is business sophistication assuming that the more advanced and established the firm structure is the quicker it will take up and make productive use of digital technologies (European Commission, 2021b).

The fourth key factor is lifelong learning, as the acquisition of digital skills is key to exploiting potential benefits from digitalisation (European Parliament Research Service and Kiss, 2017).

The fifth and final key factor is labour market efficiency. This facilitates the development of new digital skills and the matching of those skills with labour demand spurred by new or digitally restructuring economic activities (European Parliament Research Service and Kiss, 2017).

All five key factors are combined into a single joint score (see Section A4 in the Appendix for methodological details). The results are illustrated using the traffic light scheme in the left panel in Figure 3. From a geographical perspective, regions with a higher readiness for the digital transition are mostly urban and metropolitan regions across Europe, while regions with lower readiness are located in Eastern Europe (in particular Poland, Hungary, Bulgaria and Romania) and Southern Europe (in particular Spain, Italy and Greece). Regions in Northern Europe are more likely to be better positioned for the digital transition than their counterparts in Southern and Eastern Europe.

Figure 3: Readiness for the digital transition leading to deviations in economic growth potential (left panel) and strongest deviations from general economic growth potential for EU NUTS-2 regions caused by the digital transition (right panel)



Notes: The left panel shows the joint score of the five key factors for digital readiness (labour productivity, internet access, business sophistication, lifelong learning and labour market efficiency), with regions grouped into four categories according to their digital readiness. The scoring procedure is described in Section A4 in the Appendix. The right panel shows regions with low (high) potential for economic growth further lowered (increased) by the digital transition in red (green). Source: Eurostat and own calculations. Map: wiiw and Bertelsmann Stiftung.

From a specialisation perspective, metropolitan regions that specialise in knowledge-intensive services show the highest potential to benefit from the digital transition as they tend to be better equipped in terms of technical infrastructure than others. In addition, they offer more opportunities to engage in the digital economy owing to a strong business environment and highly flexible and vibrant labour markets. In contrast, industrial regions tend to benefit less from the digital transition than urbanised regions as the potential for developing new digital products and services is lower. Rural regions specialised in agriculture are expected to benefit the least from digitalisation. This is due to their comparatively low endowment with digital infrastructure and low levels of digital skills, as well as a lack of "digital" companies.

The right panel in Figure 3 combines information on the general growth potential as established in Section 2.2 with that on readiness for the digital transition. It shows regions with low general growth potential and a low level of digital readiness in red and regions with high general growth potential and a high level of readiness in green. In other words, regions in red (green) with current low economic growth potential will grow even slower (faster) due to the digital transition than other EU regions. Challenged regions are mostly located in Southern Europe – Southern Italy, Portugal or Spain – or in the Eastern parts of Central and Eastern European countries like Poland, Romania, Bulgaria, Hungary or Slovakia.

Overall, the digital transition is likely to consolidate regional disparities across Europe as the better prepared regions are once again those with the highest level of economic development (see Figure A3 in the Appendix). Regions with an already high growth potential exhibit higher levels of digital readiness and are bound to benefit from the digital transition. These regions are mainly highly urbanised areas (capital cities and other metropolitan areas) and highly industrialised and high-tech intensive regions such as Strední Cechy in Czechia, Stuttgart, Oberbayern or Braunschweig in Germany, Emilia-Romagna in Italy or Dolnoslaskie in Poland to cite a few examples.

4.2 Deviations in economic growth potential caused by the green transition

To analyse the impact of the green transition on regional growth potential, we assess the readiness of regions using four key factors. The selection of the key factors follows from the analysis carried out in Section 3.2. Based on the current level of these key factors we assess the readiness for the green transition for each EU NUTS-2 region. Regions with a high (low) level of green readiness are expected to have a higher (lower) potential for economic growth than we assessed in Section 2.2.

The first key factor is the number of road vehicles per inhabitant. This key factor proxies the transport sector, which is a significant emitter of greenhouse gases. The assumption is that the higher the number of vehicles per capita, the greater the challenge to switch to environmentally sustainable forms of transport (Boston Consulting Group, 2021).

The second key factor is CO_2 intensity (CO_2 emission per unit of GDP). The assumption is that regions with a higher CO_2 intensity (indicating a specialisation in CO_2 intensive industries) are more challenged by the green transition than regions with low CO_2 intensity (Alexandri et al., 2018).

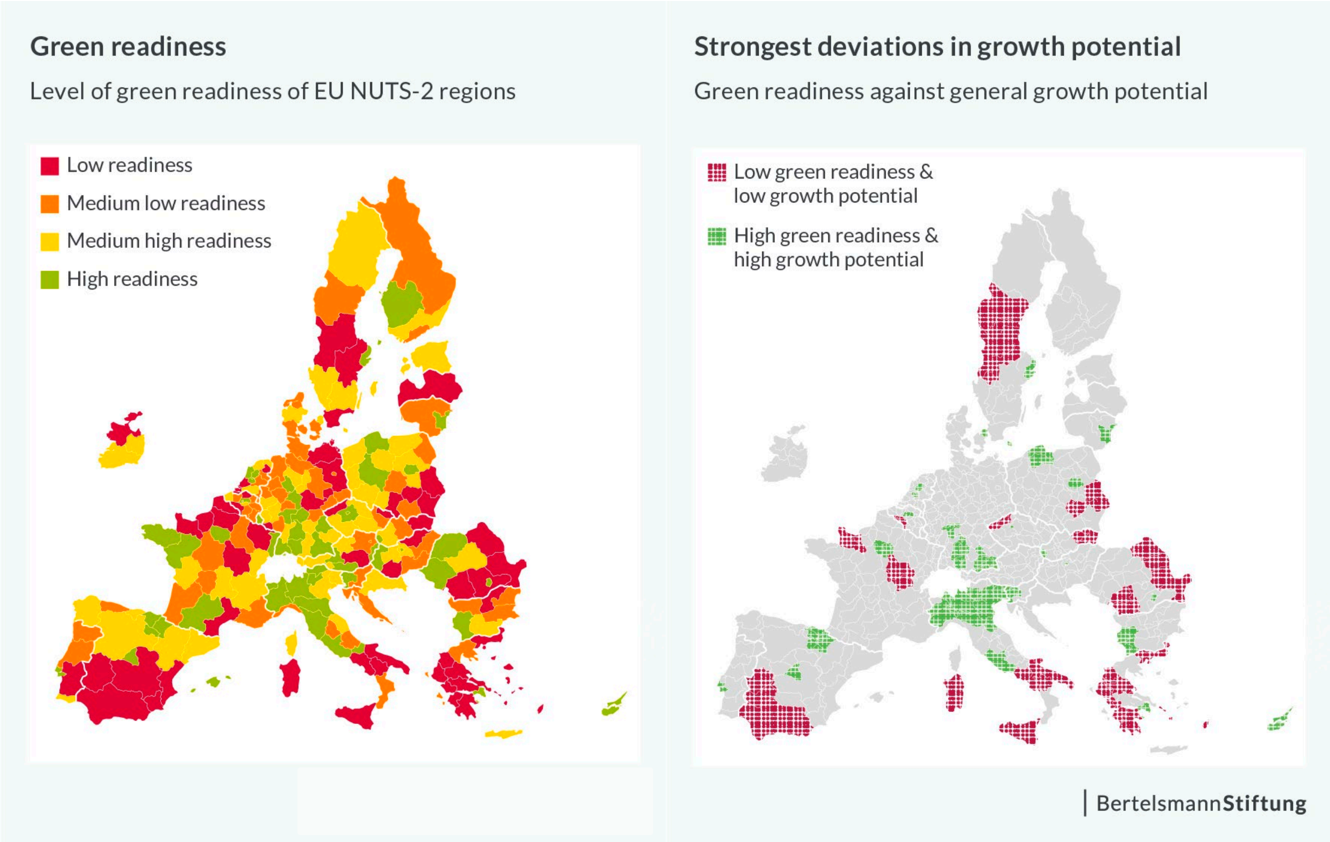
As third key factor we additionally use greenhouse gas intensity (greenhouse gas emission per unit of GDP), which includes all greenhouse gases, except CO_2 (Alexandri et al., 2018).

The fourth key factor is an index for the "burdensome cost of housing" which illustrates the challenge of reducing CO_2 emissions in domestic heating (Prognos et al., 2021). As housing is one of the major CO_2 emitters, reducing these emissions through energy saving investments is a necessity. The hypothesis is that the bigger the burden of housing costs in the first place (in relation to income levels), the more challenging it is to deploy such energy saving investments.

All four key factors are combined in a single joint score (see Section A5 in the Appendix for methodological details). The results are illustrated using the traffic light scheme in the left panel in Figure 4.

In geographical terms, clear disparities emerge between Europe's core around the Alpine area – where most of the regions with the highest level of readiness for the green transition are located – and the rest of Europe. Southern Spanish, Italian and Greek regions as well as regions located along Europe's Eastern border – from Bulgaria up to Latvia – are again expected to face the greatest challenges. In addition, many regions in the North of France and the East of Germany face poorer prospects for economic growth caused by the green transition. Highly competitive and innovative European regions that have the ability to develop and produce the environmentally friendly technologies needed exhibit higher levels of readiness for the green transition of their economy. In most cases these are economically the strongest regions.

Figure 4: Readiness for the green transition leading to deviations in economic growth potential (left panel) and strongest deviations from general economic growth potential for EU NUTS-2 regions caused by the green transition (right panel)



Notes: The left panel shows the joint score of the four key factors for green readiness (number of road vehicles, CO_2 intensity, greenhouse gas intensity and burdensome cost of housing) with regions grouped into four categories according to their green readiness. The scoring procedure is described in Section A5 in the Appendix. The right panel shows regions with low (high) potential for economic growth further lowered (increased) by the green transition in red (green). Source: Eurostat and own calculations. Map: wiiw and Bertelsmann Stiftung.

In terms of sectoral specialisation, knowledge-intensive services regions demonstrate once again the highest level of readiness for the green transition (see Figure A6 in the Appendix). Their advantage is twofold. First, their production is in the main less CO_2 intensive than in other regions and they have a relatively high share of public transport that facilitates cuts in transport related emissions. Thus, the urbanised, knowledge-intensive services regions are less challenged by the green transition than others. Second, the metropolitan regions are centres of innovation. This will have positive economic repercussions if they can play an active part in the development of green technologies that will be in high demand over the decades to come. Other regions, in particular those specialised in carbon intensive industries like steel or basic chemicals, will face more challenges than regions specialised in non-carbon intensive industries, largely because of the need to invest in new, green production technologies or environmentally sustainable forms of energy supply. This additional investment need, which will not necessarily provide a boost to output, is expected to lower the growth potential of more carbon intensive regions (partly due to crowding out effects) in the years ahead.

The right panel in Figure 4 combines the information from general growth potential with that on readiness for the green transition. It shows regions with low general growth potential and a low level of green readiness in red and regions with high general growth potential and high levels of green readiness in green. In other words, regions in red (green) with already low (high) economic growth potential will grow even slower (faster) due to the green transition than other EU regions. As with the digital transition, the regions with low levels of green readiness and low growth potential are predominantly found in Southern Europe, including Greece, Italy, and Spain, but also include agricultural regions in Romania and Poland, and carbon-intensive industry and mining regions in France, Czechia, Slovakia or Sweden. By contrast, regions with high potential for economic growth and high levels of readiness for the green transition are mostly highly urbanised areas, that is capital cities and other metropolitan areas. These include Bratislavský kraj in Slovakia, Île de France in France and Lombardia in Italy, among others.

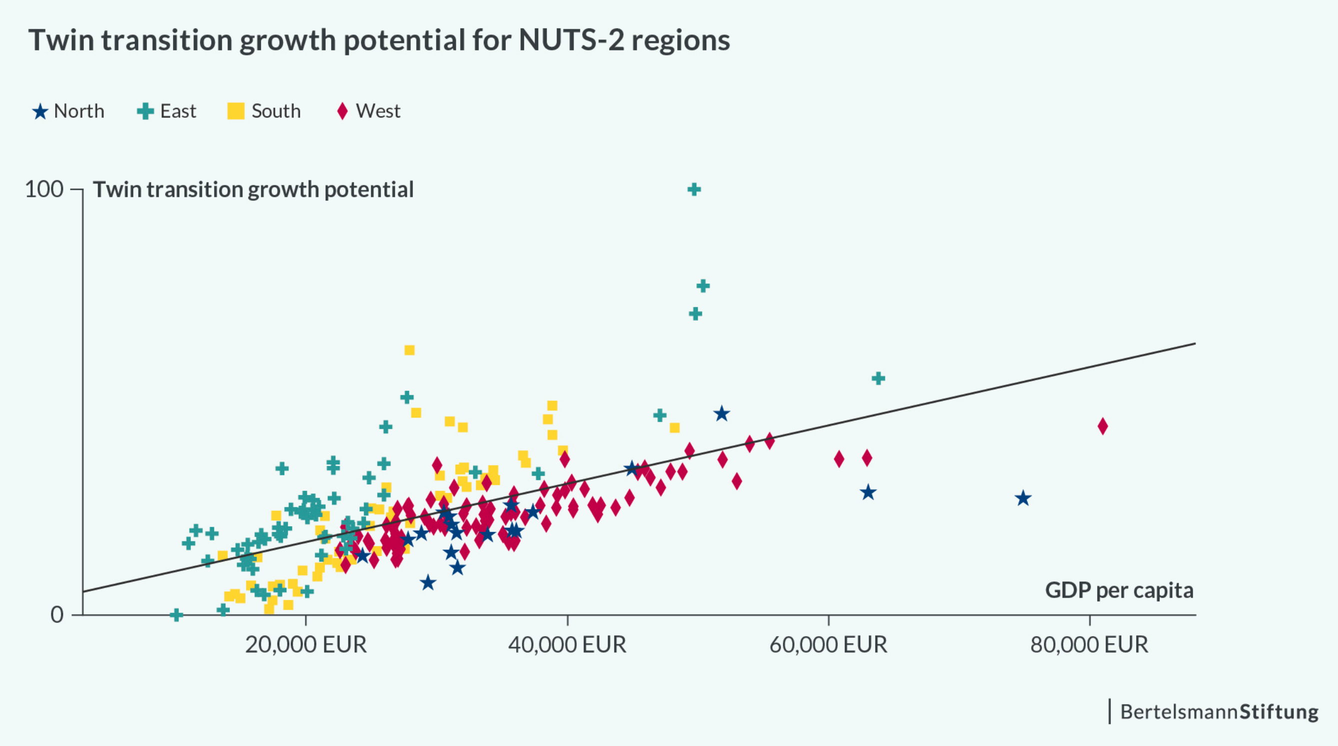
Overall, the green transition is likely to consolidate current regional disparities across Europe as regions most ready for climate neutrality are once again those with the highest level of economic development (see Figure A7 in the Appendix). Regions already enjoying strong potential for economic growth exhibit higher levels of green readiness and will, thus, stand to gain extra benefit from the green transition. The regions with high levels of green readiness are mostly the same as those with high levels of digital readiness.

4.3 Outlook on economic cohesion in Europe

Our analysis suggests that both the digital and green transitions are likely to amplify the future trend of an increasing polarisation in regional income levels, caused by fundamental differences in potential for economic growth across EU NUTS-2 regions. On the one hand, the already economically strong metropolitan regions as well as regions specialised in high-tech intensive manufacturing industries will benefit most from the digital transition, as they display not only the highest readiness to apply digital technologies in the production of their goods and services, but have the highest readiness to develop such digital technologies and thus to be at the forefront of the digital transition at the same time. On the other hand, these regions exhibit equally high levels of readiness for the green transition as they have a lower share of carbon or greenhouse gas intensive production. Moreover, given their high innovation potential, these metropolitan and high-tech regions are more likely to develop and produce green technologies than others, seeing a further boost to growth from the digital and green transition.

Therefore, we expect that the twin transition will lead to an increase in regional disparities. This is corroborated by Figure 5 that shows the correlation of regions' combined twin transition growth potential on the y-axis with their GDP per capita levels in 2019 on the x-axis. The twin transition growth potential is the potential for economic growth of EU NUTS-2 regions as determined in Section 2.2 adjusted for deviations caused by the readiness for digital transition outlined in Section 4.1 as well as that for the green transition outlined in Section 4.2 (for methodological details see Section A6 in the Appendix). Strikingly, regions with a higher level of GDP per capita are endowed with a higher twin transition growth potential. These regions are predominantly found in Western and Northern Europe. Regions in Southern Europe with already poor economic performance exhibit the lowest twin transition growth potential. However, some regions in Southern Europe exhibit a high twin transition growth potential and thus prospects for catching up. For Eastern European regions the overall picture is brighter with some regions having the highest twin transition growth potential in Europe. Overall, our results suggest a future increase in regional divergence across EU NUTS-2 regions, with economically strong regions pulling ahead of less developed ones in the phase of the twin transition.

Figure 5: Twin transition growth potential against current economic prosperity by geographical location



Notes: Twin transition growth potential (joint score of general growth potential, digital readiness and green readiness) against current GDP per capita (2019, measured in purchasing power standards). R^2 = 0.6221. The scoring procedure is described in Section A6 in the Appendix. Source: Own calculations. Chart: wiiw and Bertelsmann Stiftung.

Disparities will intensify in numerous areas in the EU with economically strong regions pulling ahead and those already struggling falling further behind (see Figure A8 in the Appendix). In Germany, border regions in the West and East are facing lower potential for economic growth than regions located in the "spine" running all the way from Bavaria and Baden-Württemberg in the South to the city states of Hamburg and Bremen in the North. In France, the economically strong regions of Paris, Rhône-Alpes and Midi-Pyrénées have the highest levels of readiness for the twin transition, in contrast to the agricultural Bourgogne region in the centre of the country and the low-tech and high-tech carbon intensive manufacturing regions in the North.

In Bulgaria, Poland and Romania, regions located at the EU external borders (mostly agricultural regions) display low general growth potential and low levels of readiness for the digital and green transition even though they enjoyed the fastest growth rates in recent years. Capital city regions as well as regions concentrating foreign direct investment (FDI) display higher potential for economic development. In Czechia, Hungary and Slovakia, older industrial and mining areas located in the East, as well as the Czech North-Western regions, have a comparatively lower level of potential for growth and readiness for the digital and green transition than the respective capital city regions and regions that received significant FDI inflows in the past.

Greek regions overwhelmingly show a low potential for economic growth in the twin transition with some islands and the capital city of Athens being notable exceptions. Given that those regions experienced economic recession in recent years (see left panel in Figure 1), their development prospects are probably among the grimmest in Europe.

Taking the lens of sectoral specialisations, regions specialised in knowledge-intensive services – most of the capital cities and other urban agglomerations – show the highest potential for economic growth in the phase of the twin transition. Regions specialising in non-carbon intensive manufacturing industries, that is both low- and high-tech intensive, tend to have better prospects for economic growth in the twin transition than their carbon-intensive manufacturing counterparts. In both cases, regions specialised in high-tech manufacturing have a higher twin transition growth potential than low-tech intensive regions. Agricultural regions generally fare weakest in both their general growth potential and their readiness for the twin transition. Given their relatively low innovation potential combined with poor accessibility, a less favourable skills structure of their workforce, lower investment rates than in other regions as well as high CO_2 and greenhouse gas intensities lead to a poor prospect for economic development in the twin transition.

5 Summary and recommendations

Our results suggest that difficult times lie ahead for regional economic cohesion in the EU. High income EU NUTS-2 regions exhibit the highest potential for economic growth in the twin transition while low-income regions exhibit the lowest. Thus, there is an underlying trend towards economic divergence across the EU.

The digital and green transition are likely to amplify these diverging growth patterns in Europe. According to our analysis, their impact on regional growth depends on regions' socio-economic and territorial characteristics. Regions most ready for the twin transition are mainly metropolitan regions, specialising in the provision of knowledge-intensive services. This type of region has not only the highest potential for economic growth but is also likely to benefit most economically from the digital and green transition. By way of contrast, agricultural regions, which have the lowest GDP per capita levels in Europe, also have low potential for economic growth – and their economies are least ready for the structural changes that come with the digital and twin transition. As for the other regions, high-tech regions have a higher overall growth potential than regions specialising in low-tech manufacturing. What is more, carbon-intensive manufacturing regions (both low and high-tech) exhibit lower levels of readiness in particular for the green transition, leading to comparatively lower growth rates than in non-carbon intensive regions.

Our results have direct implications for European cohesion and cohesion policy. In the context of the twin transition, reducing existing regional disparities will become even more difficult in the years ahead. Thus, even more so than in the past, EU cohesion policy must overcome the economic forces that favour a growing agglomeration of high-value economic activities in urban and industrial centres if the Union wants to maintain its goal of economic, social and territorial cohesion as enshrined in the Treaty.

Tackling this challenge could mean novel approaches in economic development that are more tailored to the individual types of regions. In the case of agricultural regions for instance, the analysis has shown that they lag behind all other regions in terms of general growth potential as well as digital and green readiness. For these regions suffering multiple disadvantages (for example skills endowment, infrastructure, innovative capacity), optimal policies would need to address these disadvantages. This is difficult under current EU cohesion policy. Presently, the EU follows a rather sectoral approach, for example supporting R&D, SMEs, the development of skills, green investments in different policy priorities and programmes. This makes a coordinated and integrated policy approach that addresses many development needs of the least developed regions simultaneously more difficult to enact. Notably, if cohesion policy is to overcome the "natural" differences in specialisation in the EU Single Market, such integrated regional policies should most likely be accompanied by massive investments. They would be necessary to build up a critical mass of economic activity in the face of agglomeration pressures from incumbent economic centres in the EU.

For other regions that specialise predominantly in low-tech manufacturing or carbon-intensive sectors policy approaches can be more gradual, but still tailor-made to their characteristics and needs. Therefore, for such regions specific sectoral programmes, for example supporting companies and households in their green transition, might suffice to keep them on a steady path of economic development. Overall, the results of the analysis provide a strong pointer towards a more differentiated and targeted approach to cohesion policy, switching from using income-related criteria to determine the level of support towards criteria that consider the regions' characteristics and future growth potential, notably how they might fare in the ongoing twin transition.

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Appendix

A1. Finding similar regions using clustering

Different development paths of European regions

Notwithstanding EU integration efforts, regions do not follow a unique nor continuous development path (European Commission, 2022a). Instead, development paths tend to reflect the underlying characteristics of regions which are shaped by a combination of interconnected factors linked to geography, demography, productivity, physical and human capital, infrastructure and innovation, among others (OECD, 2012). Some of these factors are inherent to their geographic and geophysical features, others are inherited. These regional characteristics tend to have a major influence on the economic activities in which regions have a comparative advantage and, accordingly, on their areas of specialisation. Indeed, they remain a determining factor even if their importance diminishes over time. For example, the supply of raw materials (for example iron ore or coal) may become less valuable owing to technology advances and policy reorientation, but its role in shaping regional economies can be observed over long periods of time.

Therefore, the activities in which a region specialises significantly affect its potential for economic prosperity. They are also indicative of the region's potential to benefit from the digital and green transition, as regions specialising in activities that design, produce or use digital and green solutions will strongly benefit from the twin transition. Developing and producing such solutions is a highly R&D and skill-intensive endeavour, implying that the twin transition will favour innovative regions with an educated skills basis.

Regions showing similar specialisation patterns are likely to face similar challenges related to the digital and green transition. For example, regions with a pronounced reliance on agricultural activities need to adjust differently than regions whose economies are dominated by knowledge-intensive services. Using groups of comparable regions to estimate growth potential allows differentiating between regions well-positioned and regions ill-positioned to take up the twin transition related challenges.[2]

Yet, such regional specialisation patterns often reflect, at least to some extent, country-specific developments in economic governance and strategic management. As a result, regions will exhibit sectoral specialisations that stem both from local assets and overarching national economic frameworks. For instance, a farming region in Germany will show a very different economic set-up than a farming region in Romania, as Germany's and Romania's employment in the primary sector accounts for around 1 per cent and 22 per cent of the country's total employment (Eurostat, 2022) respectively, with different agricultural systems. To mitigate such country-specific effects and to account for underlying differences in the national levels of economic development, we define regional sectoral specialisation in relation to national averages. This means we use the ratio of regional employment (in per cent) to national employment (in per cent) for each economic sector of relevance. Doing so allows us to identify, analyse and compare EU regions' sectoral specialisations independent of the country to which they belong and to highlight potential regional disparities not only between but also within member states.

Two-step approach to cluster European regions

[2] This grouping technique is widely used in EU regional policy analysis, e.g. the definition of territorial typologies (grouping based on urbanisation levels), categories for cohesion policy eligibility (grouping based on GDP per capita levels) or clusters based on a combination of indicators related to specific issues such as research and innovation strategies (Pavone et al., 2021) and technological transformations (Capello et al., 2020).

To group the EU regions according to their patterns of specialisation, we relied on two steps that, when used in combination, provide a robust set of regional clusters.

The first step was a "manual" clustering in which regions were sorted according to their sectoral employment shares[3] in industries that are most relevant to the digital and green transition (in relation to the respective national average). Based on the prominence of sectors in the different regions, the clustering aims to group similar regions in seven groups (or clusters) together. Characteristics in terms of NACE sectors of specialisations for each of these clusters are outlined in the third column of Table A1. Hence, a region will be labelled as "agricultural" only if its share of employment in the manufacturing sectors specified below is not significantly above the national average and its share of employment in agriculture is significantly above the national average.

In a second step the manual clustering method was validated with k-means clustering routine[4] using the manual clustering as input (i.e. initial grouping variable). The rationale behind this starting condition was twofold: first, to account, here as well, for the importance of specific sectors considering the issues addressed in the study; and second, to allow for comparison between the outcomes of the two clustering methods. For the few regions that were assigned to different clusters between the two methods, an expert assessment was made to decide on the final cluster allocation. Cut-off indicator values (determining at which point a region should belong to the "next" cluster) were defined such as to ensure relatively balanced cluster sizes.

The cluster allocation resulting from the k-means clustering routine was, for the vast majority of regions, identical to that of the manual clustering. The regions that were allocated to different clusters between the two clustering methods were mostly "frontier" regions whose indicator values were close to the cut-off values of clusters. An expert assessment was made on each of these unmatched regions to decide on its final cluster allocation.

Seven idiotypic European regions

The final allocation of EU regions to seven defined clusters is depicted in Figure A1. The map shows a rather balanced allocation of Eastern and Western regions across the seven clusters. More specifically, regions located in the newer EU member states are quite evenly distributed across the first six specialisation clusters, while regions located in the older, Western EU member states are leaning more towards low-technology, carbon-intensive manufacturing and agriculture clusters. Only one in six low-technology, carbon-intensive manufacturing regions and one in seven non-manufacturing, farming regions, respectively, is in Eastern Europe, while Eastern European regions account for a quarter of the whole sample of EU regions.

Table A1: Regional clusters of specialisations

#	Regional cluster	Sectors of specialisation	NACE industry sectors
1	Regions specialised in high-technology, carbon-intensive manufacturing industries	Manufacturing of chemical and pharmaceutical products	C20 - Manufacture of chemicals and chemical products C21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations
2	Regions specialised in low-technology, carbon-intensive	Mining	B - Mining and quarrying C17 - Manufacture of paper and paper products

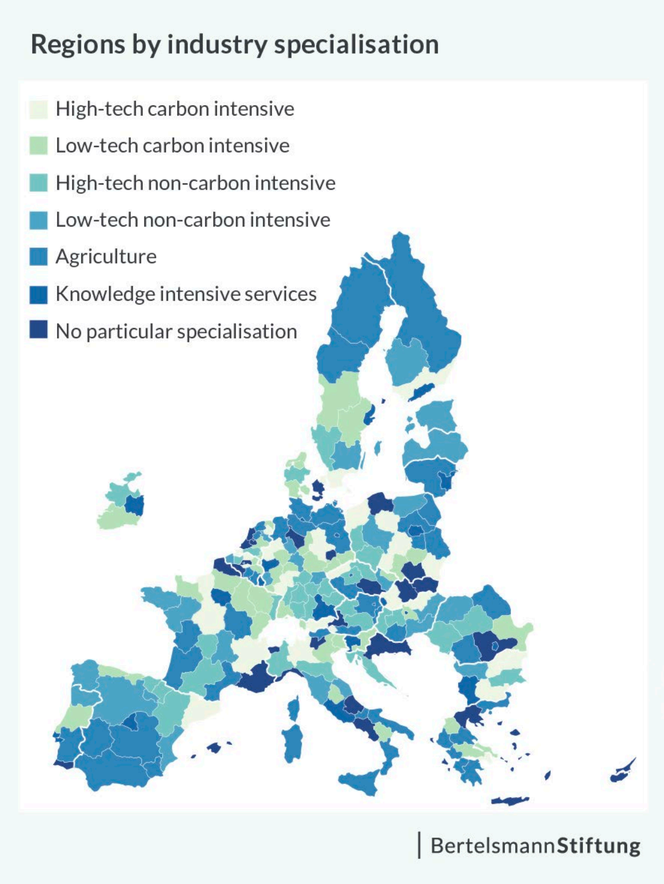
[3] Data differentiated by NACE (Rev. 2) sector have been collected from Eurostat and collated in a single database.

[4] Stata described k-means clustering as follows: "In k-means clustering, the user specifies the number of clusters, k, to create using an iterative process. Each observation is assigned to the group whose mean is closest, and then based on that categorization, new group means are determined. These steps continue until no observations change groups. The algorithm begins with k seed values, which act as the k group means. There are many ways to specify the beginning seed values." (Stata, 2021).

	manufacturing and mining industries	Manufacturing of paper, refined petroleum, metal and non-metallic mineral products except machinery and equipment	C19 - Manufacture of coke and refined petroleum products C23 - Manufacture of other non-metallic mineral products C24 - Manufacture of basic metals C25 - Manufacture of fabricated metal products, except machinery and equipment
3	Regions specialised in high-technology, non-carbon-intensive manufacturing industries	Manufacturing of electronic products, machinery and equipment, motor vehicles and other transport equipment	C26 - Manufacture of computer, electronic and optical products C27 - Manufacture of electrical equipment C28 - Manufacture of machinery and equipment (not elsewhere classified) C29 - Manufacture of motor vehicles, trailers and semi-trailers C30 - Manufacture of other transport equipment
4	Regions specialised in low-technology, non-carbon-intensive manufacturing industries	Manufacturing of food, beverages and tobacco products, textiles, wood, rubber and plastic products, printing, repair and installation of machinery and equipment	C10 - Manufacture of food products C11 - Manufacture of beverages C12 - Manufacture of tobacco products C13 - Manufacture of textiles C14 - Manufacture of wearing apparel C15 - Manufacture of leather and related products C16 - Manufacture of wood and of products of wood and cork, except furniture C18 - Printing and reproduction of recorded media C22 - Manufacture of rubber and plastic product C31 - Manufacture of furniture C32 - Other manufacturing C33 - Repair and installation of machinery and equipment
5	Agricultural regions	Agriculture, forestry and fishing	A - Agriculture, forestry and fishing
6	Knowledge-intensive services regions	Information and communication, financial, insurance, real estate, scientific and administrative activities	J - Information and communication K - Financial and insurance activities L - Real estate activities M - Professional, scientific and technical activities N - Administrative and support service activities
7	Regions with no particular specialisation	These regions are not particularly specialised in the production of tradeables	These regions are not particularly specialised in the production of tradeables

Note: The classification into high- and low-technology intensive manufacturing industries follows the Eurostat indicators on high-tech industry and knowledge-intensive services.

Figure A1: EU NUTS-2 regions by clusters of industry specialisation



Source: Eurostat and own calculations. Map: wiiw and Bertelsmann Stiftung.

A2. Determinants of economic growth

Here, we derive the key factors determining economic growth empirically for Section 2.2. We investigate the determinants of EU regional economic growth using spatial econometric techniques applied on two datasets, a panel dataset and a cross-section dataset covering 230 European NUTS-2 regions.[5] By using information on regional specialisation (clusters as defined in Section A1), we differentiate growth potentials for different industry specialisations.

We employ two spatial econometric approaches to analyse determinants of economic growth while considering spatial correlations. The first econometric approach (spatial panel) assesses the panel dataset to account for the dynamic nature of growth and changes over time. This comes at the costs of a limited number of factors affecting economic growth that can be considered. By assuming a Cobb-Douglas production function we are able to explain the relevance of different factors to achieve a certain level of economic output.

The second econometric approach (spatial cross-section) focusses on cross-sectional data observed at a single point in time. Hence, this approach lacks the time dimension but allows for the inclusion of a greater number of factors that can influence growth. This allows us to investigate whether less developed regions grow faster than more developed regions. Hence, we can test whether the beta-convergence theory (Barro et al., 1991; Barro and Sala-i-Martin, 1992) of a reduction in inequality by catching up of less developed with higher economic growth holds true for our setting.

Data

The panel dataset covers various macroeconomic regional and sectoral indicators between 2009 to 2019 sourced from Eurostat. This panel include gross domestic product, gross value added, gross fixed capital formation, and labour productivity (all expressed in constant prices). The indicators are either measuring the total economy of a region or sectors of it (agriculture, mining, manufacturing, and energy supply, public services, construction, as well as knowledge-intensive and less knowledge-intensive services). The dataset also includes demographic indicators such as regional population density, active population values as well as the level of employees' education (tertiary, secondary and primary), R&D expenditures and the size of the regions (in km^2), among other factors.

The cross-section dataset encompasses data on a wide range of macroeconomic indicators, including composite indices, sourced from Eurostat and the European Commission's Directorate-General for Regional Policy. These data include the average growth rates of real GDP, aggregate employment, compensation for employees, investment, tertiary education level employment between 2009 and 2019. Further, the average between 2009 and 2019 of labour productivity, population density, share of sectoral employment in total employment, high-skilled employment share in total employment and the 2019 Regional Competitiveness Indices (on business, innovation, accessibility indicator, labour market and heath) are included. In addition, 2009 GDP levels are used as the initial level of GDP to test the beta-convergence theory. After testing for the significance of each indicator, we use the average real GDP growth rates, investment growth rates, average share of high-skilled employment in total employment as well as 2019 composite innovation index.

Both datasets are complemented with the cluster information for each region as outlined in Section A1. To estimate the Cobb-Douglas production function, we use gross value added as dependent variable for the spatial panel approach. For testing the beta-convergence theory in the spatial cross-section approach, we employ GDP real growth rates as dependent variable.

[5] The number of NUTS-2 regions per 2016 is 240. However, the oversea regions of France, Spain and Portugal (for example La Réunion, Guadeloupe, Ceuta or Madeira) are excluded leading to a total of 230 regions used in the analysis.

For both econometric approaches we employed several model specifications to test for the statistical significance of all variables available. The final model specification for each approach entails mostly variables with statistical significance.

Spatial panel approach

We apply static spatial econometric techniques to account for time and spatial (geographical) dimensions in the data. A Cobb-Douglas production function model is assumed, whereby output (measured as gross value added) is a function of main inputs (capital and labour) used in the production process together with additional covariates.

$$\mathrm{GVA}_{rt} = \alpha + \beta_1 \mathrm{W\_GVA}_{rt} + \beta_2 \mathrm{K}_{rt} + \beta_3 \mathrm{L}_{rt} + \beta_4 \mathrm{RD}_{rt} + \beta_5 \mathrm{D}_{rt} + \beta_6 \mathrm{W\_D}_{rt} + \beta_7 \mathrm{Industry\_clusters}'_r + \mathrm{C} + \mathrm{T} + e_{rt} \quad (1)$$

$$e_{rt} = \mu_r + u_{rt}$$

The subscripts r and t represent region and year, respectively. GVA_{rt} is the dependent variable representing gross value added in region r and year t. Capital (K_{rt}) and labour (L_{rt}) are the main inputs for the production of the gross value added. RD_{rt} represents research and development that reflects the level of knowledge capital in region r in year t. D_{rt} and $\mathrm{W\_D}_{rt}$ represent the population within a region and the population within neighbourhood of a region, respectively. Together these two variables approximate for the market potential within and in the neighbourhood of a region. $\mathrm{Industry}_r$ stands for industry-specific clusters, as defined in Section A1. We include a dummy for each cluster except for the regions with no particular specialisation to capture cluster-specific differences in the level of gross value added. Thus, we compare these clusters and their effects on GVA with those of the remaining cluster. C and T stand for country and time dummies, respectively. Parameter α represents the intercept term. All continuous variables are expressed in real terms and in logarithmic form.

The remaining error term e_{rt} encompasses time-invariant regional factors affecting growth μ_r such as infrastructure and institutions, as well as the idiosyncratic unobservable elements u_{rt} that vary over regions and years. Institutions and infrastructure are two important factors affecting growth. Institutions affect economic activities through reduction of risk and reduction of production and transactions costs (North, 1991). Thus, governance and institutions are important drivers of economic development (Acemoglu et al., 2005, 2001; Rodríguez-Pose and Garcilazo, 2015; Rodrik et al., 2004). Infrastructure can directly affect growth through the reduction of transport and energy costs (Berkowitz et al., 2020; Melo et al., 2013). Macroeconomic theory perceives infrastructure as an important ingredient of technological change, that is pivotal for growth (Aschauer, 1990; Hulten and Schwab, 1991; Munnell and Cook, 1990). Both institutions and infrastructure are embodied in the unobservable time-invariant component of the error term μ_r, because they are not observable in the data. Hence, while we directly observe (and include in the model) factors of economic growth such as innovation (R&D), other factors are not directly observed in the data.

W is a spatial weight matrix used for the spatial lagging of dependent variable GVA ($\mathrm{W\_GVA}_{rt}$) and population density ($\mathrm{W\_D}_{rt}$). This symmetric matrix of size 230x230 (in terms of rows and columns) entails the relation between all the 230 regions we study. Each cell of the matrix holds a spatial weight that represents the inverse of the Euclidian distance[6] between two regions and is constructed in such a way that each region has at least one neighbour. We use the "critical cut-off distance" approach in defining matrix elements. This definition implies that two regions are neighbouring if the distance between them is below a certain threshold.[7] By interacting matrix W with gross value added ($\mathrm{W\_GVA}$) and population ($\mathrm{W\_D}_{rt}$) we get their corresponding values in the neighbourhood of each region.

[6] Euclidean distance between the centroid of two regions is a straight line in the three-dimensional space.

[7] We calculate 496 km, the minimum distance between regions allowing each region to have at least one neighbour, as critical distance.

Table A2: Random effects model results, total spatial effects

Dependent variable – GVA_{rt}		
Explanatory variables		
W_GVA_{rt}	0.111***	(0.016)
L_{rt}	0.730***	(0.021)
K_{rt}	0.338***	(0.016)
RD_{rt}	0.053***	(0.006)
D_{rt}	0.037***	(0.011)
W_D_{rt}	0.000	(0.000)
Industry clusters		
High-technology, carbon intensive industries	-0.002	(0.026)
Low-technology, carbon intensive industries	-0.005	(0.022)
High-technology, non-carbon intensive industries	-0.009	(0.023)
Low-technology, non-carbon intensive industries	-0.027	(0.024)
Knowledge-intensive service industries	0.120***	(0.031)
Agriculture	-0.066***	(0.024)
Time dummies	Yes	
Country dummies	Yes	
Test for model selection (p-values)		
Baltagi C.1 spatial error dependence	0.467	
Baltagi C.3 random effect test	0.000	
Number of years	11 (2009-2019)	
Number of observations	2530	
Number of regions	230	

Notes: * 10 per cent significance level; ** 5 per cent significance level; *** 1 per cent significance level. C.1 – LM test for spatial dependence in the error term, conditional on random effects and serial correlation. C.3 – LM test for random effects conditional on the presence of serial correlation and spatial dependence in the error term. Country and time dummies are omitted for brevity. Standard errors are in parenthesis. The full table of results is available upon request.

Our modelling strategy is based on several tests developed by Baltagi (2007) for spatial dependence in the error term conditional on the presence of serial correlation and random effects (C.1) and tests of random effects conditional on the presence of serial correlation and spatial dependence in the error term (C.3). The test results reject the presence of spatial dependence in the error term (as the p-value is higher than 0.05, see Table A2, C.1 line), but indicate the presence of random effects (as the p-value is lower than 0.05, see Table A2, C.3 line). This implies two points with respect to the modelling approach: First, gross value added is geographically dependable, but factors not included in the model directly (the error term e_{rt}) are not geographically (spatially) dependent. Second, (region-specific μ_r) unobservable effects are random, which is why spatial random effects are applied.[8]

The results are presented in Table A2. First, the estimates on capital and labour show increasing returns to scale as the sum of the two corresponding coefficients exceeds 1. Thus, output increases by a larger margin (at a higher rate) than inputs. Second, the spatial autoregressive term is positive and significant implying that there are interactions across regions through dense economic activities. Third, knowledge capital, as proxied by the level of R&D activities, has a highly significant and positive effect on output (gross value added) within a region. Fourth, demand (or market potential) in a region has a strong positive effect on value-added creation as well. However, demand in the neighbourhood of that region has no effect on its own value-added. Altogether, these estimates on the population densities reveal that consumption, on average, is very local in nature.

The coefficients related to the cluster dummies reveal that regions dominated by knowledge-intensive service industries exhibit substantial higher levels of gross value added than other regions. The opposite holds true for agricultural regions which exhibit lower levels of gross value added than other regions.

Spatial cross-section approach

The spatial cross-section approach is used to test whether less developed regions grow at a faster pace than more developed regions and are therefore on a catching-up growth convergence path (beta-convergence theory). Therefore, we are looking at growth rates (instead of levels as done in the spatial panel approach) and use average GDP growth rate as dependent variable. The following model is estimated:

$$g(GDP)_r = \alpha + \beta_1 GDP_{rt-1} + \beta_2 g(HC_r) + \beta_3 g(I_r) + \beta_4 RD_r + \beta_5 Industry\_clusters'_r + South + East + e_r \qquad (2)$$

$g(GDP)_r$ represents the 2009-2019 average growth rate of GDP as a function of the initial (2009) level of GDP (GDP_{rt-1}), the average growth rate of high-skilled labour, $g(HC_r)$ as a measure of human capital, the average investment growth rate $g(I_r)$, and the composite innovation index (RD_r). The model also includes regional dummies South and East to capture structural differences in Eastern and Southern Europe, respectively. Similar to the spatial panel approach, we include cluster dummies ($Industry\_clusters_r$). Parameter α represents the intercept term.

We varied the model specification and included additional indicators. However, all of them turned out statistically insignificant and have therefore been excluded. To rule out the possibility that these non-included indicators are affecting the error term and therefore biasing our results, we apply a set of Lagrange multiplier tests (Anselin and Bera, 1998) of spatial error and spatial lag dependence. The test results (see Table A3) show the presence of spatial error dependence (as the p-value is close to 0.05), but no evidence for spatial dependence in the dependent variable (as the p-value is above 0.05). Thus, a spatial error model is employed. For the estimation, we use the same matrix design as applied in the panel data approach.

[8] An alternative modeling spatial panel approach would be spatial fixed effects and would be applicable, if Baltagi C.3 random effects test was not rejected (p-value higher than 0.05). In such case unobservables are fixed over time (e.g. institutions) and can be eliminated by applying within transformation (i.e. model estimated with fixed effect approach).

The estimated results are presented in Table A3. The negative and significant effect of the initial level of GDP indicates that regions with a lower initial GDP level grow at a faster rate. Investment growth boosts economic growth, as indicated by the positive and significant coefficient of the investment variable. Likewise, human capital contributes to regional growth implying the importance of knowledge and skills for the growth potential. Innovation, as measured by the innovation composite index, has a positive effect on regional growth, confirming the well-established finding that innovation contributes to economic growth and competitiveness (Polder et al., 2009; Vujanović et al., 2022).

Regions located in Southern Europe grow at a slower pace than other regions (although not significantly), but regions in Eastern Europe grow faster than regions elsewhere. This is another indication of convergence processes for regions located in Eastern Europe but shows that regions located in Southern Europe are indeed in a so-called development trap (European Commission, 2022a).

Table A3: Spatial error model results, total spatial effects

Dependent variable – average GDP growth rate		
Explanatory variables		
GDP_{rt-1}	-0.00002***	(0.004)
$g(HC_r)$	0.112***	(0.032)
$g(I_r)$	0.277***	(0.022)
RD_r	0.575***	(0.126)
Industry clusters		
High-technology, carbon intensive industries	0.233	(0.222)
Low-technology, carbon intensive industries	0.221	(0.207)
High-technology, non-carbon intensive industries	0.259	(0.220)
Low-technology, non-carbon intensive industries	0.292	(0.027)
Knowledge-intensive services industries	0.237	(0.274)
Agriculture	-0.019	(0.205)
Regional dummies		
Southern Europe	-0.124	(0.187)
Eastern Europe	0.817****	(0.252)
Intercept	1.047***	(0.358)
Spatially lagged error	-0.162	(0.216)
Test for model selection (p-values)		
RLMerr (conditional error dependence)	0.053	
RLMlag (conditional spatial lag dependence)	0.088	
Number of observations	230	

Notes: * 10 per cent significance level; ** 5 per cent significance level; *** 1 per cent significance level. RLMerr is the test of spatial dependence in the error term, conditional on the spatial dependence in the dependent variable. RLMlag is the test of spatial dependence in the dependent variable, conditional on the spatial dependence in the error term. Standard errors are in parenthesis.

At the same time, regions do not show significantly different growth patterns based on their technology and carbon intensity specialisation. We find for no cluster a significant coefficient implying that there are no structural differences in the growth pace beyond the above discussed variables. The spatial error dependence term is not statistically significant, implying that factors which are not controlled for are not affecting regional growth rates.

Key factors for economic growth

In this section we investigated the determinants of the regional economic output in the EU and the potentials of future growth. We carried out multiple regressions with different specifications and find high-skilled employment, innovation and investments as key factors for economic growth. This confirms the rich economic literature suggesting positive effects (Becker et al., 2013; Charron et al., 2012; Crescenzi and Rodríguez-Pose, 2011; Polder et al., 2009). Furthermore, we assume that the error term of the regressions entails structural information on regional infrastructure and institutional quality and are therefore also driving economic growth. This is in line with the well-established macroeconomic literature which regularly highlights the importance of regional infrastructure (Fujita and Thisse, 1996) and institutional quality (Acemoglu et al., 2005, 2001; Rodríguez-Pose and Garcilazo, 2015; Rodrik et al., 2004). Even though infrastructure and institutional quality are not directly included in the model, they are contained in the (time-invariant) unobservable part of the model and determine to a good extent our modelling strategy. Therefore, we consider for assessing the general growth potential of regions the key factors of high-skilled employment, innovation, investments, regional infrastructure and institutional quality.

A3. Regional general economic growth potentials

Calculation of the joint score

In Section 2.2, general potential for economic growth in European regions is discussed. We apply a scoring approach using five key factors that assess a region's relative position in potential for economic growth. These five key factors are determined using econometric analyses in Section A2 and are listed in Table A4.

The joint score for the general potential for economic growth is calculated using the methodology outlined in Section A7.

Table A4: Key factors for assessing general growth potential

Variables	Description
High-skilled employment	Share of employed with completed tertiary education in total employment.
Institutional quality	Quality of regional public services as perceived by citizens.
Infrastructure	A composite indicator combining information on: a) population accessible within 1h30 by road, b) population accessible within 1h30 by rail and c) the daily number of passenger flights.
Investment	Investment is important from both, the supply and demand side of the economy. On the supply side it provides the capital necessary for production, while it is also a major contributor to effective demand.
Innovation	A composite innovation index including information on: a) core creativity class employment, b) knowledge workers, c) scientific publications, d) total intramural R&D expenditure, e) human resources in science and technology, f) employment in technology and knowledge-intensive sectors, g) exports in medium-high/high-tech manufacturing and h) sales of new-to-market and new-to-firms innovation.

Note: More information on the variables in Section A8.

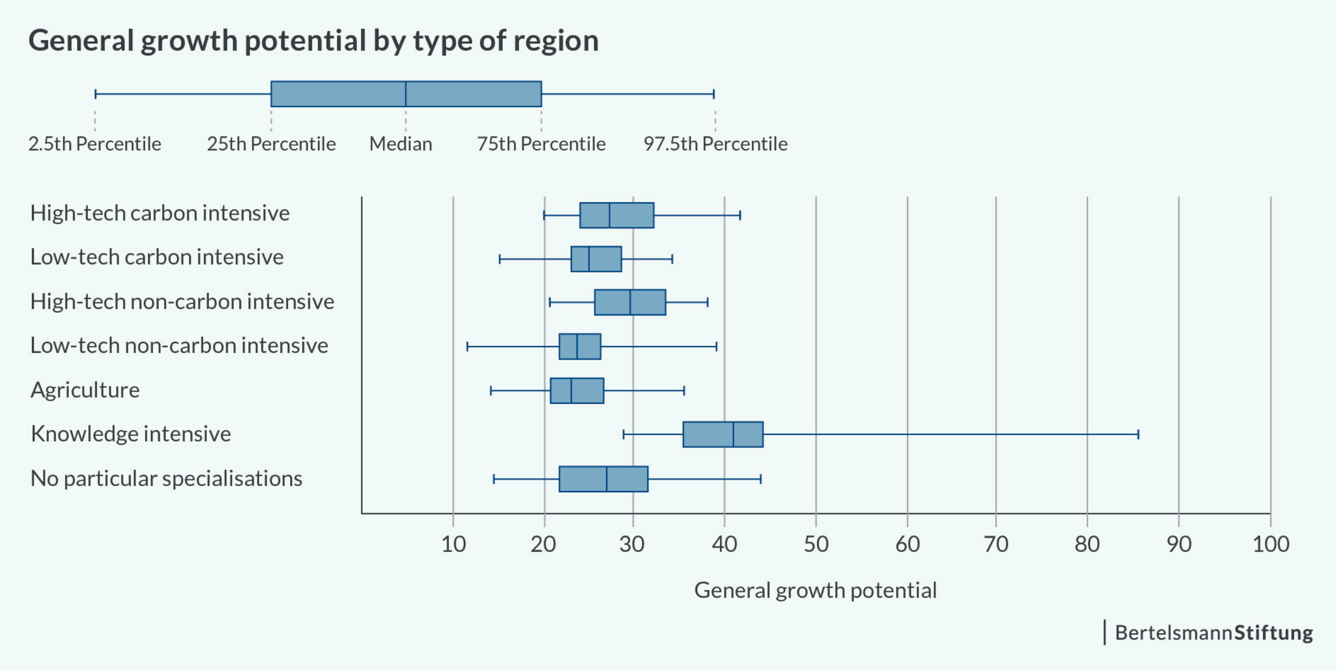
The calculated joint score is split into quartiles for Figure 2. Each quartile is highlighted according to the color-coding outlined in Table A5.

Table A5: Color-coding of general growth potential

	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
Score	0 - 23.0	23.0 - 26.2	26.2 - 32.3	32.3 - 100
Labelling	Red	Orange	Yellow	Green

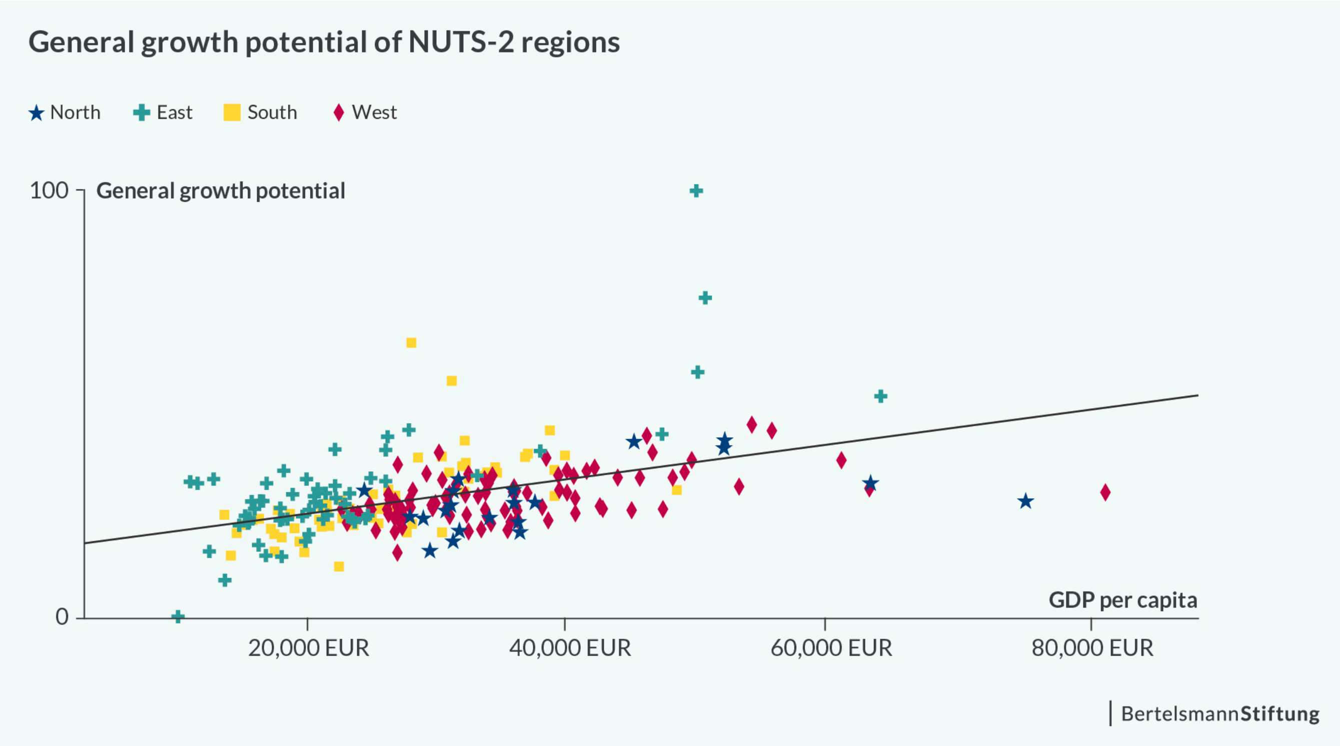
Additional Results

Figure A2: Deviations in general growth potential by type of region



Notes: Outliers (values smaller than the 2.5th or greater than the 97.5th percentile) are not shown in the graph. Boxes represent realised values between the 25th and 75th percentile for each cluster. Whiskers represent the range between the 2.5th and 97.5th percentile. Source: Own calculations. Chart: wiiw and Bertelsmann Stiftung.

Figure A3: General growth potential against current economic prosperity by geographical location



Notes: General growth potential (joint score of the five key factors for economic growth, that is high-skilled employment, institutional quality, infrastructure, investment and innovation) against current GDP per capita (2019, measured in purchasing power standards). R^2 = 0.4807. Source: Own calculations. Chart: wiiw and Bertelsmann Stiftung.

A4. Deviations in economic growth potential caused by the digital transition

Calculation of the joint score

In Section 4.1, deviations in economic growth potential caused by the digital transition for European regions are discussed. We apply a scoring approach using five key factors that assess a region's relative position in their readiness for the digital transition. These five key factors are selected based on a rigorous literature review (see Section 3.1) and an expert's assessment and are listed in Table A6.

The joint score for the deviations in economic growth potential caused by the digital transition is calculated using the methodology outlined in Section A7.

Table A6: Key factors for assessing readiness of regions for the digital transition

Variables	Description
Labour productivity	Labour productivity is used as a proxy for the level of technology.
Internet access	A composite indicator combing information on: a) internet at home, b) broadband at home, c) online interaction with public authorities and d) internet access.
Business sophistication	A composite business sophistication index including information on: a) employment (sectors K-N), b) gross value added (sectors K-N), c) innovative SMEs collaborating with others and d) marketing or organisational innovators.
Lifelong learning	Percentage of persons aged 25 to 64 who stated that they received education or training.
Labour market efficiency	A composite labour market efficiency including information on: a) employment rate (excluding agriculture), b) long term unemployment, c) unemployment, d) productivity, e) gender balance unemployment, f) gender balance employment, g) female unemployment, h) people not in education, employment or training (NEET) and i) involuntary part-time /temporary employment.

Note: More information on the variables in Section A8.

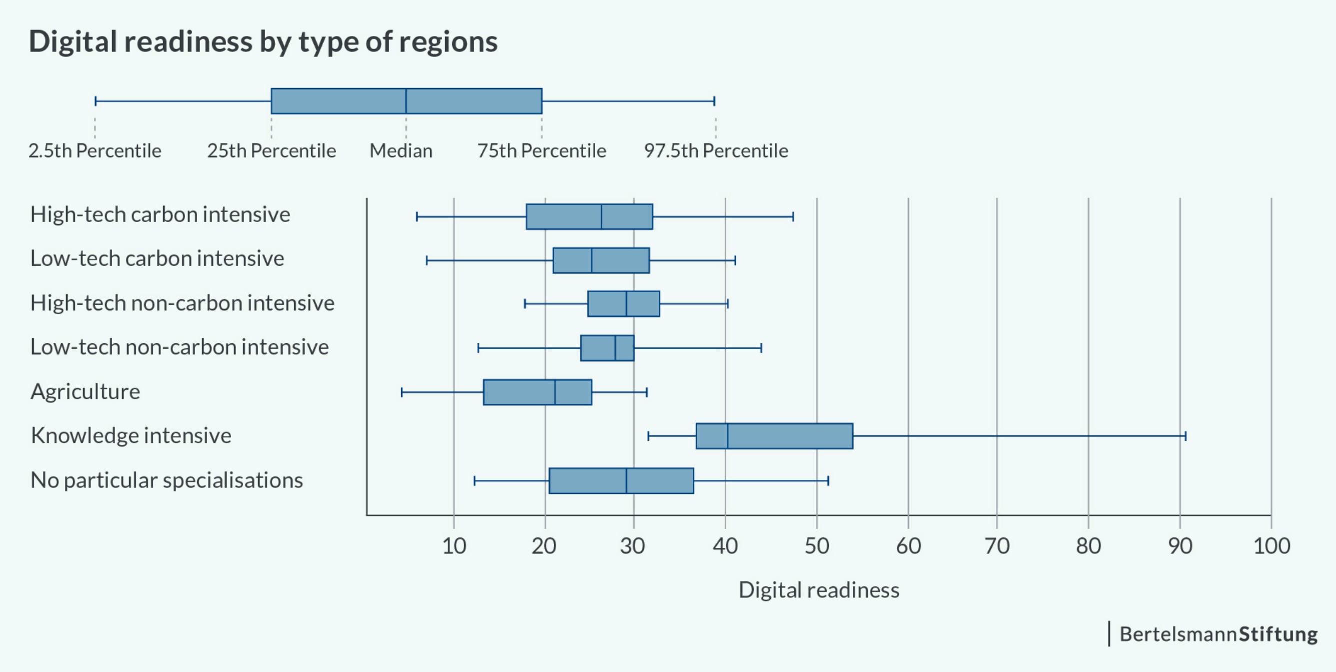
The calculated joint score is split into quartiles for Figure 3. Each quartile is highlighted according to the color-coding outlined in Table A7.

Table A7: Color-coding of deviations in general growth potential caused by the digital transition

	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
Score	0 - 20.9	20.9 - 27.2	27.2 - 32.6	32.6 - 100
Labelling	Red	Orange	Yellow	Green

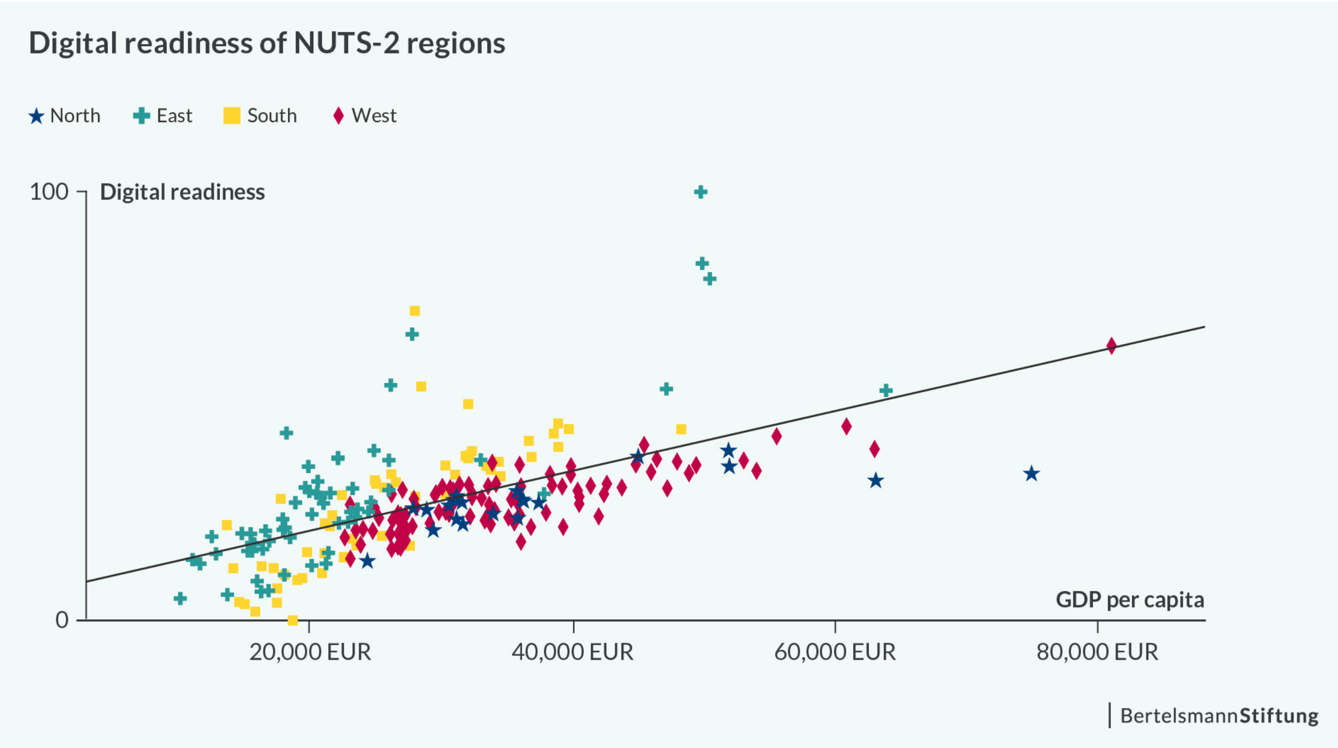
Additional Results

Figure A4: Deviations in economic growth potential caused by the digital transition by type of region



Notes: Outliers (values smaller than the 2.5th or greater than the 97.5th percentile) are not shown in the graph. Boxes represent realised values between the 25th and 75th percentile for each cluster. Whiskers represent the range between the 2.5th and 97.5th percentile. Source: Own calculations. Chart: wiiw and Bertelsmann Stiftung.

Figure A5: Digital readiness against current economic prosperity for regions by geographical location



Notes: Digital readiness (joint score of the five key factors for digital readiness, that is labour productivity, internet access, business sophistication, lifelong learning and labour market efficiency) against current GDP per capita (2019, measured in purchasing power standards). R^2 = 0.6167. Source: Own calculations. Chart: wiiw and Bertelsmann Stiftung.

A5. Deviations in economic growth potential caused by the green transition

In Section 4.2, deviations in economic growth potential in European regions caused by the green transition are discussed. We apply a scoring approach using four key factors that assess a region's relative position in their readiness for the green transition. These key factors are selected based on a rigorous literature review (see Section 3.2) and an expert's assessment and are listed in Table A8.

The joint score for the deviations in economic growth potential caused by the green transition is calculated using the methodology outlined in Section A7.

Table A8: Key factors for assessing readiness of regions for the green transition

Variables	Description
Number of road vehicles	Number of road vehicles per capita, including cars, trucks, motorbikes.
CO_2 intensity	Estimated data using regional NACE rev. 2 2-digit employment data and national NACE rev. 2 2-digit data on CO_2 emissions per industry
Greenhouse gas intensity	Estimated data using regional NACE rev. 2 2-digit employment data and national NACE rev. 2 2-digit data on greenhouse gas emissions per industry.
Burdensome cost of housing	Percentage of people living in a dwelling where housing costs (mortgage repayment or rent, insurance and service charges) are a financial burden.

Note: More information on the variables in Section A8.

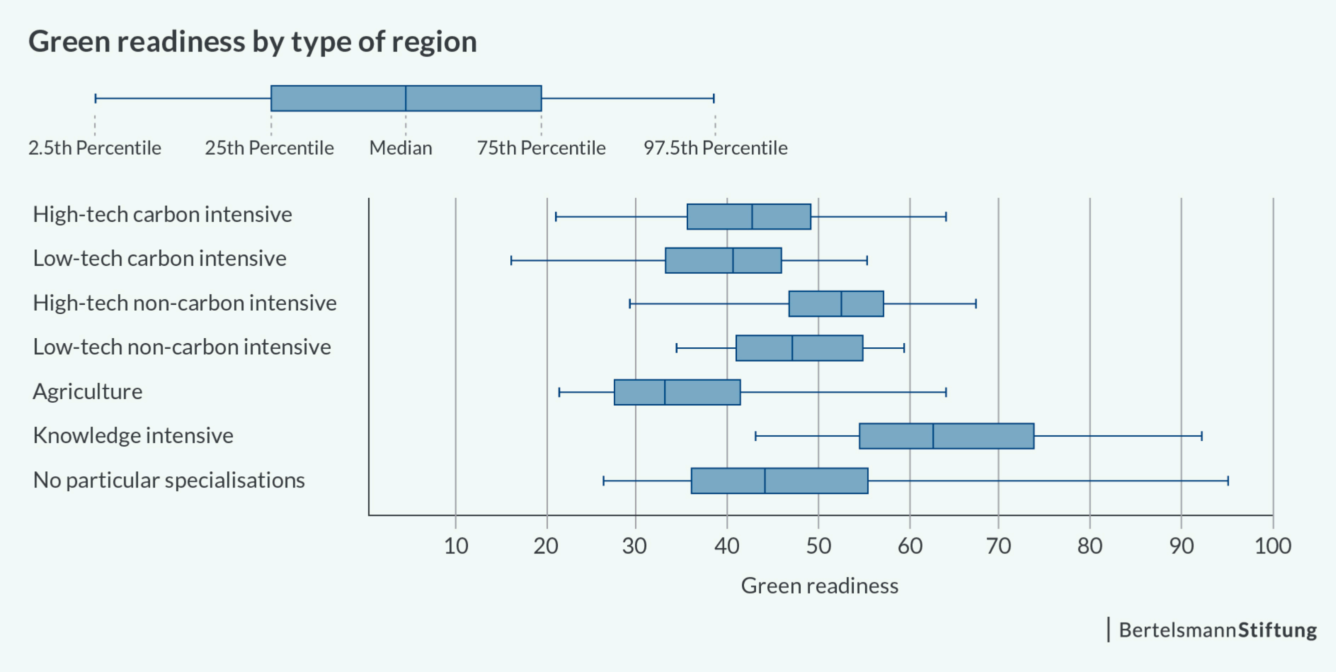
The calculated joint score is split into quartiles for Figure 4. Each quartile is highlighted according to the color-coding outlined in Table A9.

Table A9: Color-coding of deviations in general growth potential caused by the green transition

	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
Score	0 - 42.6	42.6 - 51.6	51.6 - 56.9	56.9 - 100
Labelling	Red	Orange	Yellow	Green

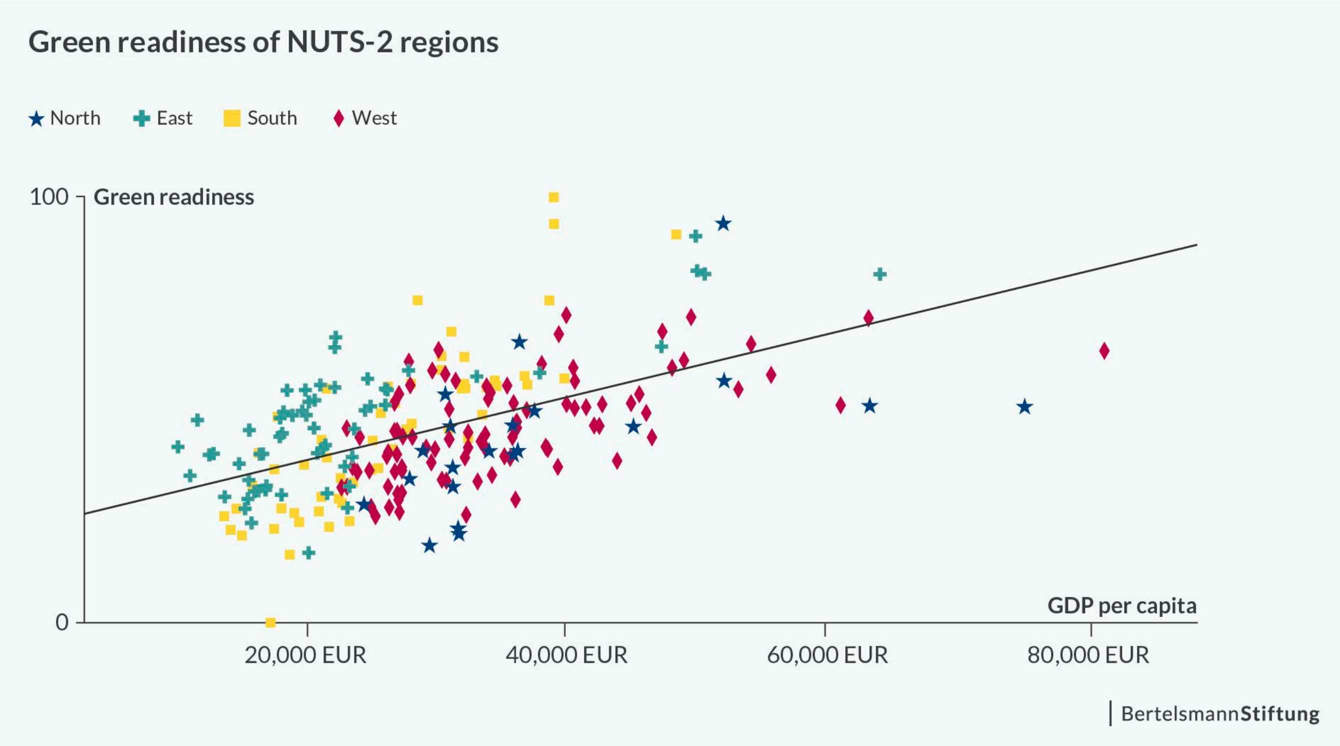
Additional Results

Figure A6: Deviations in economic growth potential caused by the green transition by type of region



Notes: Outliers (values smaller than the 2.5th or greater than the 97.5th percentile) are not shown in the graph. Boxes represent realised values between the 25th and 75th percentile for each cluster. Whiskers represent the range between the 2.5th and 97.5th percentile. Source: Own calculations. Chart: wiiw and Bertelsmann Stiftung.

Figure A7: Green readiness against current economic prosperity for regions by geographical location



Notes: Green readiness (joint score of the four key factors for green readiness, that is number of road vehicles, CO_2 intensity, greenhouse gas intensity and burdensome cost of housing) against current GDP per capita (2019, measured in purchasing power standards). R^2 = 0.5569. Source: Own calculations. Chart: wiiw and Bertelsmann Stiftung.

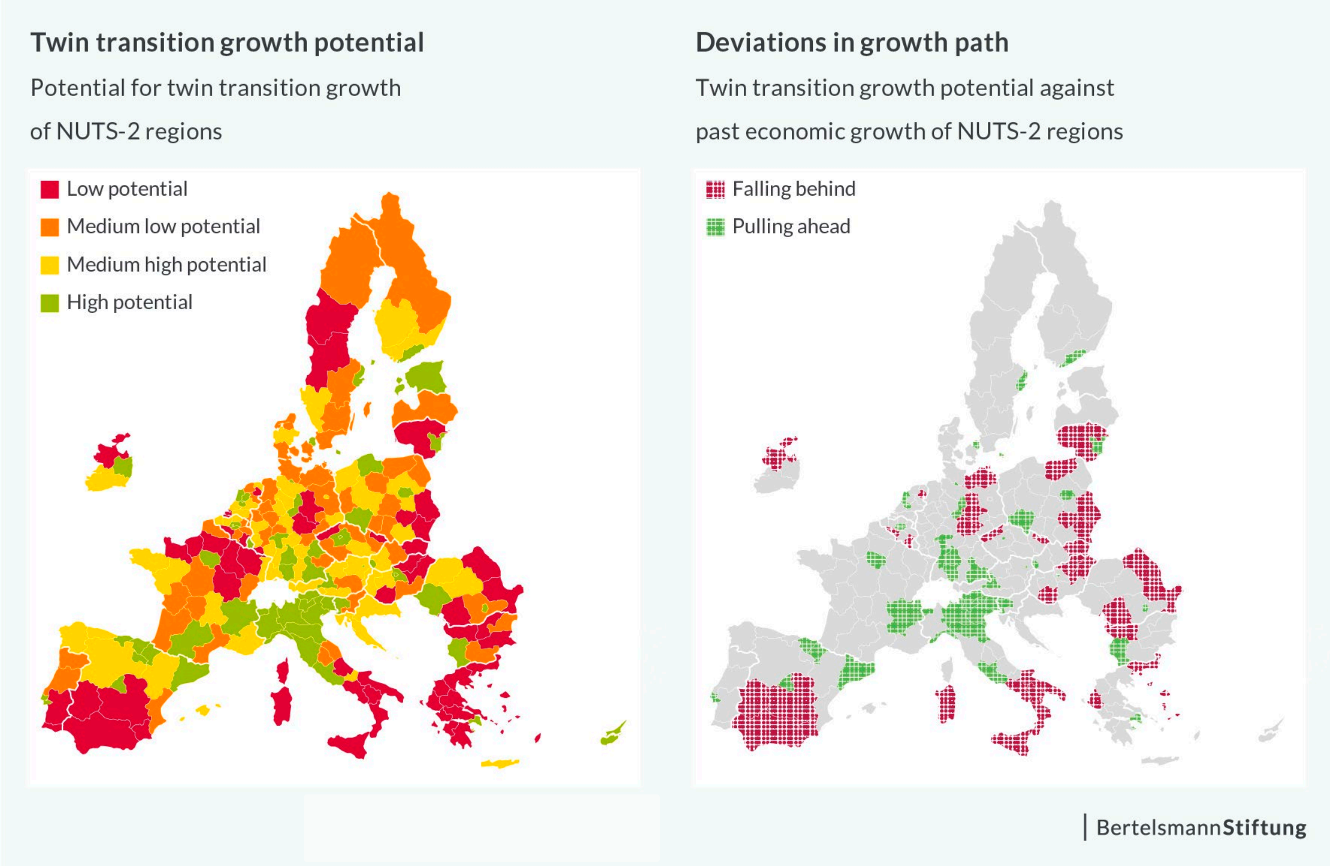
A6. Potential for economic growth in the face of the twin transition

In Section 4.3 we discuss the twin transition growth potential of the EU NUTS-2 regions combining the general growth potential results with the deviations caused by the digital and green transition. Methodologically, we take the unweighted average of the three respective scores to get an overall score for the twin transition growth potential. The goal of this analysis is to provide an overall assessment of the region's future growth prospects in the phase of the twin transition and to draw implications on future EU cohesion.

Table A10: Overview lower and upper limit of quartile for twin transition growth potential

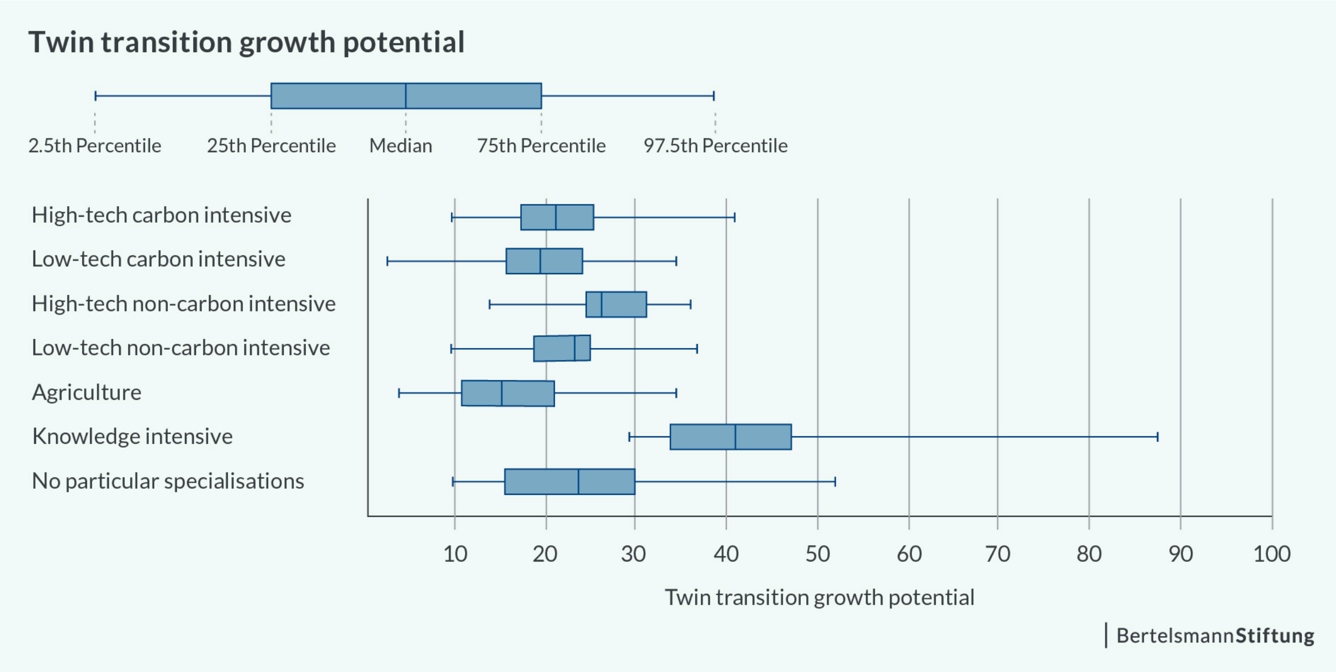
	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
Score	0 - 17.6	17.6 - 23.8	23.8 - 29.6	29.6 - 100
Labelling	Red	Orange	Yellow	Green

Figure A8: Twin transition growth potential for EU NUTS-2 regions and strongest deviations from past economic growth



Notes: The left panel shows the twin transition growth potential (joint score of general growth potential, digital readiness and green readiness) with regions grouped into four categories. The right panel shows regions with substantially worse (red) or better (green) potential for economic growth in the face of the twin transition than in the past. Source: Eurostat and own calculations. Map: wiiw and Bertelsmann Stiftung.

Figure A9: Twin transition growth potential by type of EU NUTS-2 regions and strongest deviations from past economic growth



Notes: Outliers (values smaller than the 2.5th or greater than the 97.5th percentile) are not shown in the graph. Boxes represent realised values between the 25th and 75th percentile for each cluster. Whiskers represent the range between the 2.5th and 97.5th percentile. Source: Own calculations. Chart: wiiw and Bertelsmann Stiftung.

A7. Calculation of scores

We assess the regional economic growth potential and the deviations thereof caused by the digital and green transition using a scoring approach. By looking at four to five indicators (key factors) jointly, we assess the relative position of a region. The higher the resulting single-valued score, the better the potential for future growth.

The construction of each score follows, with minor modifications, the Regional Competitiveness Index method (Annoni and Dijkstra, 2019; Joint Research Centre et al., 2010). This means the analysis includes the following steps:

1. Data transformation
2. Calculation of country-relative indicators
3. Normalisation
4. Calculation of the score

We check for potential asymmetries in the distributions of the indicators to establish comparability when summing the scores up. In such cases, the respective indicators need to be transformed to make them “more symmetric, more linear, and more constant in variance. Transformation are monotonic, to preserve order relation, and have in general the effect of either expanding or contracting the distances to extreme observations on one side of the median, making distributions more symmetric around their central location” (Joint Research Centre et al., 2010).

The first step is data transformation. To detect asymmetries in the indicator data, we look at the skewness κ, this is the adjusted third moment divided by the cube of the standard deviation:

$$\kappa = \frac{n}{(n-1)(n-2)} \sum_{i=1}^{n} \frac{(x-\bar{x})^3}{s^3}$$

with *n* being the number of EU NUTS-2 regions, $\bar{x}$ the arithmetic mean and *s* the respective standard deviation. A positive (negative) κ indicates outliers on the right-hand (left-hand) side of the distribution.

Following the Regional Competitiveness Index method, we transform the data if $|\kappa| > 1$. In this case we use a Box-Cox transformation of the form:

$$\Phi_\lambda = \frac{x^\lambda}{\lambda} \text{ if } \lambda \neq 0$$

In case $\kappa > 1$ we set $\lambda = -0.05$, in case $\kappa < 1$ $\lambda = 2$, to correct for positive and negative skweness, respectively. For three indicators, namely the “Number of road vehicles per inhabitant”, “Greenhouse gas intensity” and “CO_2 intensity”, this transformation was applied.

The second step is to derive country-relative indicators. The purpose is to eliminate country-specific effects to end up with values comparable all over the EU. The country-relative indicators are derived by dividing the indicator values by the respective country averages.

The third step is the normalisation of the country-relative indicators. Even though the country-relative indicators are all distributed around mean 1, normalisation is recommended to increase the comparability of the individual indicators. For normalisation, we use a standard z-score transformation, so that every country-relative indicator has mean 0 and standard deviation of 1.

In a final step, the score is calculated as the average of the respective indicators z-score. Additionally, the score is rescaled to range between 0 and 100.

A8. Data for key factors

Table A11: Overview data used for key factors

Variable	Unit	Description	Source
GDP	Euro (purchasing power standards), 2019	Gross domestic product	ARDECO database
GDP growth	Per cent	Annual average growth rates	ARDECO database
High-skilled employment	Per cent of total employment	Share of employed with completed tertiary education in total employment	Eurostat
Institutional quality	Index value	Quality of governance indicator, developed by the Quality of Government Institute, Gothenburg University	Social Progress Index 2020
Infrastructure	Index value	Composite index including information on the regions' accessibility by road, rail and air.	Regional Competitiveness Index 2019
Investment	Per cent of GDP	Gross fixed capital formation	ARDECO database
Innovation	Index value	Composite index including information on patenting, knowledge related employment, scientific publications, R&D and innovation activities	Regional Competitiveness Index 2019
Labour productivity	Ratio of GDP and employment	GDP per employed person	ARDECO database
Internet access	Index value	Composite index including information on household internet access, internet use and mobile phone use	Social Progress Index 2020
Business sophistication	Index value	Composite index including information on employment and gross value added in "sophisticated" sectors, FDI intensity, strengths of regional clusters, the use of venture capital	Regional Competitiveness Index 2019
Lifelong learning	Per cent of population	Share of population engaged in lifelong learning	Social Progress Index 2020
Labour market efficiency	Index value	Composite index including information on the employment situation, job mobility, female employment, public labour market expenditures	Regional Competitiveness Index 2019
Number of road vehicles per inhabitant	Value per inhabitant	Based on Eurostat series: "Stock of vehicles by category and NUTS-2"	Eurostat, own calculations
Greenhouse gas intensity	Tons of greenhouse gas emissions (CO_2 equivalents) per unit of GDP	Estimated based on a regionalisation of national greenhouse gas emissions data; GHG includes all greenhouse gas except CO_2	Eurostat, own estimations
CO_2 intensity	Tons of CO_2 emissions per unit of GDP	Estimated based on a regionalisation of national CO emissions data	Eurostat, own estimations
Burdensome cost of housing	Index value	Percentage of people living in a dwelling where housing costs	Social Progress Index 2020

		(mortgage repayment or rent, insurance and service charges) are a financial burden.	

A9. Region-specific scoring results

Table A12: Joint scores for each region, alphabetical order

Region	Region name	Area	Cluster	Regional growth potential	Readiness digital transition	Readiness green transition	Twin transition growth potential
ITF1	Abruzzo	South	7	21.9	19.7	36.3	15
FI20	Åland	North	7	19.8	27.8	65.9	0
PT18	Alentejo	South	5	23.1	14.7	28.1	11.3
PT15	Algarve	South	7	19.8	17.4	45.5	15.6
FRF1	Alsace	West	3	28	24.9	58.4	26.1
EL51	Anatoliki Makedonia, Thraki	South	5	14.4	12.2	21.8	4.4
ES61	Andalucía	South	5	21.1	15.7	29.6	11.1
FRI1	Aquitaine	West	5	26.2	29.3	37.7	21.4
ES24	Aragón	South	3	33.8	30.2	45.6	27.5
PT17	Área Metropolitana de Lisboa	South	6	41.3	50.5	62.5	44.1
DEA5	Arnsberg	West	2	20	29.6	44.7	20.5
EL30	Attiki	South	1	37.4	54.6	75.8	47.5
FRK1	Auvergne	West	4	23.4	30.5	53.8	24.9
ITF5	Basilicata	South	2	21.5	17.5	33	13
FRD1	Basse-Normandie	West	2	20.2	23.9	25	12.9
DE30	Berlin	West	6	37.3	34.1	41.4	29.6
FRC1	Bourgogne	West	5	22.7	22.4	28.9	14.5
DE40	Brandenburg	West	5	35.7	24.5	30.3	21.9
SK01	Bratislavský kraj	East	6	74.9	79.7	82	77.3
DE91	Braunschweig	West	2	32.6	40.9	53.7	33.6
DE50	Bremen	West	7	25	36.4	51.6	27.6
FRH0	Bretagne	West	4	25.6	28.3	55.8	25.7
BE10	Brussels	West	6	30.1	40	71.6	36.9
RO32	Bucuresti–Ilfov	East	6	100	100	90.9	100
HU11	Budapest	East	6	42.8	54	64.9	46.9
AT11	Burgenland (AT)	West	5	27.3	22	61.4	25.3
ITF6	Calabria	South	5	15.3	7.5	36.1	6.7
ITF3	Campania	South	7	20.7	9.4	25.8	7.3
ES13	Cantabria	South	2	29.9	34.1	55.5	30
ES41	Castilla y León	South	4	28.4	24.6	51.7	24.3
ES42	Castilla-la Mancha	South	5	27.3	14.8	34	14.9
ES51	Cataluña	South	1	33	36.1	48.9	30.5
FRB0	Centre –Val de Loire	West	1	25.8	23	39.5	19.1
PT16	Centro (PT)	South	2	24.6	22	38.8	17.9
RO12	Centru	East	3	26.9	32.4	52.3	27
FRF2	Champagne-Ardenne	West	2	24.1	18.7	35.8	15.5
DED4	Chemnitz	West	2	23.2	17.2	45	17
ES30	Comunidad de Madrid	South	6	43.7	43.6	75.8	46
ES22	Comunidad Foral de Navarra	South	3	33.8	33.6	55.6	31.7
ES52	Comunitat Valenciana	South	4	23.2	32.7	35.9	20.9
FRM0	Corse	West	5	15	17	45.1	13
DE71	Darmstadt	West	1	32.6	37.1	59.9	33.7
HU33	Dél-Alföld	East	4	27.1	20.9	39.7	18.9

HU23	Dél-Dunántúl	East	5	27	17.9	23.4	13.2
DEA4	Detmold	West	4	20.3	28.2	55.7	23.1
PL51	Dolnoslaskie	East	3	32.5	39.6	50.9	32.3
NL13	Drenthe	West	1	21	21.8	36.6	15.5
DED2	Dresden	West	2	33.6	22.7	41.2	23.1
DEA1	Düsseldorf	West	1	22.6	31.5	40.8	21.5
EL63	Dytiki Ellada	South	5	21.6	3.8	20.5	3.9
EL53	Dytiki Makedonia	South	2	20.6	12.2	0	1.4
IE06	Eastern and Midland	North	6	31.3	32.6	50.9	28.8
EE00	Eesti	East	4	42.2	54.9	54.7	44.2
ITH5	Emilia-Romagna	South	3	38.3	38.2	56	35.7
HU32	Észak-Alföld	East	4	21.4	20.3	37.4	15.3
HU31	Észak-Magyarország	East	1	23.7	16.2	26.8	11.8
FI1C	Etelä-Suomi	North	1	26.1	28.1	46.1	23.2
ES43	Extremadura	South	5	22.8	11	26.2	9.1
NL23	Flevoland	West	5	38.5	31.2	64.1	35.2
FRC2	Franche-Comté	West	2	23.7	21.3	43.6	18.5
DE13	Freiburg	West	2	30.4	27.3	51.6	26.4
NL12	Friesland (NL)	West	5	23.2	21	43.8	18.2
ITH4	Friuli-Venezia Giulia	South	2	36.1	38.6	55.1	34.7
ES11	Galicia	South	4	25.3	31	49.3	24.8
NL22	Gelderland	West	2	29.2	27	44.3	23.6
DE72	Gießen	West	2	28.6	31.6	38.8	23.8
NL11	Groningen	West	2	24.9	31.3	47.2	24.2
DE60	Hamburg	West	6	36.7	45.3	51.1	36.6
DE92	Hannover	West	7	29.5	36.3	46.8	28.4
FRD2	Haute-Normandie	West	1	25	24.6	30.6	16.9
FI1B	Helsinki-Uusimaa	North	6	41	38.2	46.1	34.4
DK01	Hovedstaden	North	1	41.4	35.9	56.9	36.5
FR10	Île de France	West	6	43.7	43	58.3	40.9
ES53	Illes Balears	South	7	19.8	36.2	62.7	28
EL62	Ionia Nisia	South	7	15.1	15.9	37.1	10.5
EL54	Ipeiros	South	5	19.6	4.3	26.8	4.9
HR03	Jadranska Hrvatska	East	3	32.3	30.1	48.8	27.6
CZ06	Jihovýchod	East	7	31.8	30.4	51.2	28.2
CZ03	Jihozápad	East	5	23	25.3	49.9	21.6
DE12	Karlsruhe	West	3	34.2	31.4	50.7	29.6
AT21	Kärnten	West	5	23.4	22.5	55.6	22.1
DE73	Kassel	West	4	21.9	25.7	54.1	22.4
EL52	Kentriki Makedonia	South	7	23	12.6	39.9	13.6
DEB1	Koblenz	West	2	23.8	27.5	50.2	23
DEA2	Köln	West	6	29.1	36	51.4	29.3
HR04	Kontinentalna Hrvatska	East	7	28.3	29.7	45.8	24.7
HU21	Közép-Dunántúl	East	3	26	27.3	55.9	25.5
EL43	Kriti	South	7	25	28.4	48.4	23.4
PL61	Kujawsko-Pomorskie	East	1	22.9	21.6	44.5	18.5
CY00	Kypros	South	7	64.3	72.2	56.2	62.2
ES23	La Rioja	South	4	37.6	29.5	59.4	32.8
FRJ1	Languedoc-Roussillon	West	5	25.1	26.3	27.2	16.8
FI19	Länsi-Suomi	North	4	24.8	26.8	53.6	24.1
LV00	Latvija	East	4	23.8	29.7	30.4	18.5

ITI4	Lazio	South	6	35.1	37	56.9	34
DED5	Leipzig	West	7	32.1	25.4	33.6	21.4
ITC3	Liguria	South	7	32.4	39.5	43.4	30.1
NL42	Limburg (NL)	West	2	24.9	24	39.1	19
FRI2	Limousin	West	3	22	27	45.7	20.7
PL71	Lódzkie	East	1	29	15.8	41.8	18.2
ITC4	Lombardia	South	1	37.8	44.6	57.4	38.6
FRF3	Lorraine	West	2	24.1	21	36.6	16.6
PL81	Lubelskie	East	5	22.2	18	33.5	13.7
PL43	Lubuskie	East	3	22.9	19.4	54.6	20.3
DE93	Lüneburg	West	5	28.7	29.5	32	21.1
LU00	Luxembourg	West	6	29.2	64.1	63.9	44.4
PL21	Malopolskie	East	7	30	28.8	39.8	23.5
MT00	Malta	South	6	55.4	34	68.4	45.5
ITI3	Marche	South	4	21.7	28.9	46.8	21.6
PL92	Mazowiecki regionalny	East	5	23.6	31	49.8	24.1
DE80	Mecklenburg-Vorpommern	West	5	27.5	23.4	27.1	16.7
SE32	Mellersta Norrland	North	5	20.1	22.4	20.8	11.1
FRJ2	Midi-Pyrénées	West	3	31.1	31.7	56.9	29.9
DK04	Midtjylland	North	3	26.8	27.4	49.7	24.2
DE25	Mittelfranken	West	3	35	24.3	46.3	25.8
ITF2	Molise	South	5	26.6	22	55	23.3
CZ08	Moravskoslezsko	East	2	23.5	25.3	27	15.5
DEA3	Münster	West	1	23.6	30.3	43.1	22.1
DE22	Niederbayern	West	3	22.8	18.4	45.8	17.5
AT12	Niederösterreich	West	5	33.5	28.8	41.2	25.6
NL41	Noord-Brabant	West	3	27.8	27.2	50.5	24.8
NL32	Noord-Holland	West	7	30.5	37.3	54.9	31.4
RO21	Nord-Est	East	5	8.5	6	29.6	1.2
DK05	Nordjylland	North	2	23.2	24.9	40.3	18.9
FRE1	Nord-Pas-de-Calais	West	7	27.1	20.2	35.5	17.5
RO11	Nord-Vest	East	4	17.7	35.9	54.7	24.8
SE31	Norra Mellansverige	North	2	15.4	21	18.1	7.6
PT11	Norte	South	4	25.8	22.6	43	19.9
IE04	Northern and Western	North	3	29.6	13.8	27.7	13.9
EL42	Notio Aigaio	South	7	11.8	29.2	29.1	12.2
HU22	Nyugat-Dunántúl	East	3	27.8	22.7	67.1	27.4
DE21	Oberbayern	West	6	45.1	34.9	65.5	40.2
DE24	Oberfranken	West	4	22.2	22.9	38.7	17.1
AT31	Oberösterreich	West	3	24.3	28.9	56.8	25.5
DE23	Oberpfalz	West	3	29.7	21.8	67.8	28.2
PL52	Opolskie	East	1	25.5	21.2	48.1	20.5
SE12	Östra Mellansverige	North	2	29.5	29	31.9	21.2
NL21	Overijssel	West	4	25.1	24.9	41.2	20
SE33	Övre Norrland	North	5	26.7	23.9	39.4	19.8
ES21	País Vasco	South	3	37.5	41.9	58	37.5
FRG0	Pays-de-la-Loire	West	4	25.5	29.7	59.3	27.1
EL65	Peloponnisos	South	5	19.4	4.1	22	3.5
HU12	Pest	East	2	34.3	43.7	49.6	34.4
FRE2	Picardie	West	2	24.1	17.7	35.4	15
ITC1	Piemonte	South	3	35.3	38.4	55	34.2

PL82	Podkarpackie	East	1	25.3	9.2	30.8	10.8
PL84	Podlaskie	East	5	27.2	16.6	39.6	17.1
FI1D	Pohjois- ja Itä-Suomi	North	5	23	25.8	40.4	19.2
FRI3	Poitou-Charentes	West	5	19.9	24.9	51.7	20.5
PL63	Pomorskie	East	7	39.3	37.8	55.3	35.9
CZ01	Praha	East	6	51.8	53.6	81.9	55.6
ES12	Principado de Asturias	South	2	28.7	31.9	42.8	25.1
BE21	Prov. Antwerpen	West	1	32.7	31	38	25.2
BE31	Prov. Brabant wallon	West	1	42.5	34.7	49.3	34.4
BE32	Prov. Hainaut	West	7	22.1	14.4	32	11.7
BE33	Prov. Liège	West	2	25.2	20.1	39.2	17.5
BE22	Prov. Limburg (BE)	West	2	26.6	25.3	40.8	20.8
BE34	Prov. Luxembourg (BE)	West	5	25.3	19.4	31.8	15.2
BE35	Prov. Namur	West	5	26.3	20.9	35.8	17.4
BE23	Prov. Oost-Vlaanderen	West	3	32.3	31.3	41.6	26.2
BE24	Prov. Vlaams-Brabant	West	7	34.3	34	72.3	36.6
BE25	Prov. West-Vlaanderen	West	4	29.3	28.2	43.6	24
FRL0	Provence-Alpes-Côte d'Azur	West	7	28.9	27.2	43.2	23.3
ITH1	Provincia Autonoma di Bolzano/Bozen	South	5	29.7	44.6	91.3	44
ITH2	Provincia Autonoma di Trento	South	7	34.4	46	100	49.2
ITF4	Puglia	South	5	17.6	9.9	23.7	5.5
ES62	Región de Murcia	South	5	25.4	19.1	23.9	13
DEB3	Rheinhessen-Pfalz	West	1	33.2	31.9	34.7	24.9
FRK2	Rhône-Alpes	West	1	31.3	36.8	52.6	31
DEC0	Saarland	West	2	20.5	23.3	42.6	17.6
DEE0	Sachsen-Anhalt	West	1	24.1	16.7	40	15.8
AT32	Salzburg	West	7	25.2	30.8	68.4	30
ITG2	Sardegna	South	5	21.3	24.6	22.5	13
DEF0	Schleswig-Holstein	West	5	25.4	30.8	33.4	20.5
DE27	Schwaben	West	3	29.1	21.8	50	23
BG32	Severen tsentralen	East	1	31.7	14.2	34.6	16.8
BG33	Severoiztochen	East	1	32.3	15.5	39.7	19.1
CZ05	Severovýchod	East	3	22.2	26	45.6	20.3
CZ04	Severozápad	East	1	19.3	12.8	16.4	5.5
BG31	Severozapaden	East	4	0	5.1	41.3	0
ITG1	Sicilia	South	5	18.6	10.6	26.9	7.1
DK02	Sjælland	North	7	23.4	26.1	33.8	17.7
PL22	Slaskie	East	2	28.9	30.8	32.1	21.8
SE21	Småland med öarna	North	4	17.7	23.6	36.4	14.7
LT01	Sostines regionas	East	6	38.9	29.6	58.7	33.2
IE05	Southern	North	2	27.1	34.2	50.7	27.4
AT22	Steiermark	West	3	25.8	24.7	28.9	16.9
EL64	Sterea Ellada	South	2	24.1	0	16	2.4
SE11	Stockholm	North	6	39.6	39.6	93.8	47.3
SK03	Stredné Slovensko	East	7	22.6	23.6	43.7	19
CZ02	Strední Cechy	East	3	39.1	37.4	55	35.6
CZ07	Strední Morava	East	4	23	24	38.9	18
DE11	Stuttgart	West	3	34	34.4	61.7	33.7
RO31	Sud - Muntenia	East	7	31.3	18.5	32.2	17.8
RO22	Sud-Est	East	2	14.1	10.6	30.1	5.9
RO41	Sud-Vest Oltenia	East	5	14.3	6.9	31.2	4.8

PL72	Swietokrzyskie	East	2	16.8	6.7	31	5.8
DK03	Syddanmark	North	2	22.2	28.2	40.4	19.8
SE22	Sydsverige	North	1	32.3	27.6	22.1	19.3
EL61	Thessalia	South	5	22.7	2	32.3	7
DEG0	Thüringen	West	2	25.6	18	26	13.2
AT33	Tirol	West	1	25.9	29.5	46.3	23.7
ITI1	Toscana	South	4	29.3	37.8	56.2	31.4
DEB2	Trier	West	4	29.6	26.4	43.6	23.4
DE14	Tübingen	West	3	33	30.3	59.9	31.1
ITI2	Umbria	South	2	25.1	32.3	40.8	22.9
DE26	Unterfranken	West	3	25.7	25.1	60.8	25.7
NL31	Utrecht	West	7	36.8	36.2	71.8	38.6
ITC2	Valle d'Aosta/Vallée d'Aoste	South	7	28.3	40.5	93.7	42.3
SE23	Västsverige	North	3	29.7	30.2	46.4	25.7
ITH3	Veneto	South	2	33.9	35.1	55.3	32.2
RO42	Vest	East	3	30.7	38	64.7	34.5
LT02	Vidurio ir vakaru Lietuvos regionas	East	5	22.9	13.3	41	14.1
AT34	Vorarlberg	West	2	25.3	31.9	51.3	25.8
EL41	Voreio Aigaio	South	7	23.9	22.3	25	13.9
SK04	Východné Slovensko	East	7	21.9	20.2	29.1	13.3
SI03	Vzhodna Slovenija	East	2	26.4	22.9	36.7	18.6
PL62	Warminsko-Mazurskie	East	4	23.2	16.2	45.3	16.6
PL91	Warszawski stoleczny	East	6	57.4	83.3	82.7	70.8
DE94	Weser-Ems	West	5	28.3	28.5	33.2	20.9
PL41	Wielkopolskie	East	4	23.8	27.6	57.3	24.9
AT13	Wien	West	6	38.6	37.7	43.6	32.3
BG34	Yugoiztochen	East	3	15.3	19.6	39.4	12.7
BG41	Yugozapaden	East	6	43.8	66.8	59.3	51.1
BG42	Yuzhen tsentralen	East	1	31.3	13.2	47.6	19.8
PL42	Zachodniopomorskie	East	1	28.7	27.5	48.7	24.8
SI04	Zahodna Slovenija	East	6	33.1	37.5	57.9	33.5
SK02	Západné Slovensko	East	1	25.1	24.8	51.9	22.9
NL34	Zeeland	West	1	23.9	24.3	25.4	14.9
NL33	Zuid-Holland	West	7	33.2	31.3	36.6	25.2

Notes: EU area refers to the geographical location of a region in Europe. Cluster refers to a region's industry specialisation. 1 = high-tech carbon intensive; 2 = low-tech carbon intensive; 3 = high-tech non-carbon intensive; 4 = low-tech non-carbon intensive; 5 = agriculture; 6 = knowledge-intensive services; 7 = no particular specialisation. The clustering procedure is described in Section A1. The procedures for calculating the scores for the regional growth potential, the readiness for the digital transition, the readiness for the green transition and the twin transition growth potential are outlined in Sections A3 – A6.

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