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Challenges to regional competitiveness in the face of the twin transition¹

Abstract: Regional competitiveness has long been assessed through indicators focused on current performance, productivity, and living standards, yet emerging megatrends - particularly the green and digital (twin) transitions - challenge these traditional approaches. This study questions whether high competitiveness, as measured by RCI 2.0, corresponds to regions' capacity to adapt to structural transformations. Using a synthetic Twin Capacity index for EU NUTS-2 regions, combining vulnerability and transformation readiness, the analysis reveals a lack of correlation between traditional competitiveness and adaptive capacity. The findings show significant regional diversity, identifying both leaders and regions at risk of transformation despite strong economic positions. The results highlight the need to reinterpret competitiveness as a dynamic, adaptation-oriented concept and to adjust policy instruments to better reflect diverse regional capabilities.

Keywords: regional competitiveness, region, EU, green transition, digital transition, dual transition

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1. An introduction to regional competitiveness

Competitiveness is one of the most important concepts in economics, particularly from the perspective of the megatrends shaping the modern global economy, such as: the rapid development of artificial intelligence, digital transformation, climate change, the energy transition towards renewable energy sources, demographic changes linked to an ageing population, the shift in the global geopolitical balance of power, and deglobalisation (Garretsen et al., 2025; Pictet Group, 2025; Sulmicka, 2016). In recent years, the European Union has addressed the issue of competitiveness in numerous strategic documents outlining a long-term vision for its development, such as the Draghi Report and the Competitiveness Compass (e.g., Draghi & European Commission, 2024; European Commission, 2025).

The concept of competitiveness, originally applied to businesses, as in Michael Porter's framework (Porter, 1990), has also been applied to cities, regions and national economies. In the context of regional competitiveness, it is important to note that a region is situated within a regional, national and international system of regulations, institutions and standards; it follows a specific development path shaped by its historical, social and economic context; and it is embedded in a network of connections linking its key stakeholders; hence, when discussing regional competitiveness, it must be defined differently from the competitiveness of enterprises (Czyżewska, 2012, p. 204).

Competition between regions can take various forms: from direct to indirect forms related to competition for foreign direct investment, highly skilled workers, subsidies and other forms of support from the central budget, EU aid, the location of national or international institutions, the organisation of cultural and sporting events, international conferences, etc. The forms of regional competition change over time, which is also linked to the changing factors of regional competitiveness over the years and depends, among other things, on the strategies adopted by regional authorities.

Regional competitiveness is a multifaceted concept; it is defined in various ways in the literature. A review of the definitions of this concept (Czyżewska, 2012) reveals its interpretative diversity, and thus its scope is equated with areas such as: economic strength, adaptability to changing socio-economic conditions, productivity, the ability to create new (attractive) conditions for development, the region's strengths, or the determinants and dynamics of the region's long-term prosperity. In the long term, it is precisely the creation of conditions conducive to socio-economic prosperity that should be the objective of measures to enhance regional competitiveness (Grassia et al., 2024). Regional competitiveness is, moreover,

a relative concept, meaning that a region's competitive position can only be determined in relation to other regions serving as benchmarks in this analysis. For these two reasons, regional competitiveness is often treated in the literature as a *fuzzy concept* (Bristow, 2010; Kitson et al., 2004).

The extension of the concept of competitiveness to the territorial and regional levels has, for several decades, stimulated debate among researchers interested in this field, whilst highlighting their often conflicting approaches to the issue. Researchers convinced of the importance of applying the concept of competitiveness at the regional level have, in recent years, conducted in-depth studies of the factors of regional competitiveness from economic and social perspectives. When discussing the factors of regional competitiveness, their considerable diversity is once again emphasised (resulting, amongst other things, from the conditions outlined above). Various authors regard as determinants (competitiveness factors) those components considered to be its cause or condition. In recent years, there has been a decline in the significance of certain regional competitiveness factors (e.g. productivity), whilst, on the other hand, there has been an increase in the role of determinants such as education, social change and technologies, including digital technologies (Grassia et al., 2024: 101). Regional competitiveness factors, much like factors influencing the location of economic activity, evolve over time: from traditional factors such as labour, land and capital to largely intangible factors such as knowledge, innovation, network connections, international cooperation, human and relational capital (e.g. Fantechi & Fratesi, 2024; Camagni & Capello, 2013; Aiginger & Firgo, 2017).

Recent research on regional competitiveness indicates that it cannot be assessed solely on the basis of current economic advantages, as transformation processes (e.g. green and digital) lead to profound structural changes that redefine the sources of advantage. Baumgartinger-Seiringer et al. (2025) propose a 'transformative resilience' approach, in which the key factor is the ability of regions to adapt and transform their economic structures in response to the challenges of the twin transition. Traditional measures of competitiveness (including *the EU Regional Competitiveness Index*, RCI) are insufficient, as they do not account for regions' capacity for adaptation and transformation under current conditions (Karman et al., 2024; Kostarakos et al., 2025). Therefore, the regional capacity for structural change and building resilience is of key importance, as it determines long-term competitiveness. The aim of the study is to critically review the traditional approach to regional competitiveness by incorporating the dimension of adaptive capacity into the analysis of the green and digital transitions. The study aims to test the hypothesis that a high level of competitiveness does not

necessarily imply high adaptability, and thus, economically developed regions may remain vulnerable to transformation risks. By constructing the synthetic Twin Capacity index and analysing its relationship with RCI, the study seeks to redefine regional competitiveness as a concept encompassing not only current economic efficiency but also the capacity for long-term adaptation and structural transformation.

2. Twin transition and competitiveness in the European Union's activities

In recent years, the European Union has devoted considerable attention to the changes taking place amid a multi-crisis environment (Ladi & Polverari, 2025). This involves a range of measures relating to *the so-called twin transition*, namely the climate and digital transitions. Undoubtedly, these processes affect the competitive position of economies at the EU, national, regional and sectoral levels. These transitions reinforce regional advantages but may also exacerbate inequalities – particularly between digitally advanced regions and those with weaker resources, infrastructure, and skills. The EU is undertaking a wide range of actions and adopting numerous strategic documents designed to accelerate the transition (see Table 1).

Table 1. EU strategic documents and their significance for the twin transition

Document / strategy / tool	Significance for the twin transition	Sources
The European Green Deal (EGD)	A strategy underpinning the green transition, combined with digitalisation as its key catalyst	Komninou et al., 2025, Benedix et al., 2025
The EU's New Industrial Strategy	Introduces the twin transition as a central element of industrial policy	García et al., 2025
Digital Strategy and 2030 Digital Compass	Sets out digital objectives: skills, infrastructure, business transformation	(Panori, 2024b, Chatzistamoulou, 2023)
NextGenerationEU and National Recovery Plans (RRF)	The main source of funding for the twin transition in the regions	Arshad et al., 2025, Celeste Dominioni, 2024
Fit for 55, REPowerEU	Legislative package and EU programme accelerating the energy transition and low-carbon investments within the EES	Lenz, 2025
Net-Zero Industry Act & Critical Raw Materials Act	Strengthen the competitiveness of the green technology sector	Paliova, 2024
New Digital Skills Development Plan	Reducing the skills gap between EU regions	Maucorps et al., 2023
EU Mission (Horizon Europe) – Climate-neutral cities	Integrating digital technologies with the energy transition	Panori, 2024a)

Source: own work.

A number of measures included in programmes, policies and specific financial instruments assigned to them have a regional impact. These include, amongst others:

- Transition Pathways, i.e. roadmaps prepared by the Commission, outlining requirements for sectors and regions to accelerate the twin transition (Panori, 2024a).
- Strengthening digital and green skills through EU funds (European Regional Development Fund, European Social Fund+, Cohesion Fund; Caravella et al., 2023).
- Funding for innovation under the Horizon Europe programme, the mechanisms and instruments of the European Innovation Council, and instruments supporting small and medium-sized enterprises in the green and digital transition, which are scattered across EU policies such as cohesion policy and agricultural policy (Güdelek et al., 2025).
- The integration of digitalisation into energy and efficiency policies (e.g. the digitalisation of building renovation, data interoperability; cf. Hwang et al., 2025).
- Regulations on the circular economy and sustainable production (CEAP 2020, Right to Repair, in: Benedix et al., 2025; Prapiestyte, 2026).
- Just transition mechanisms under the Just Transition Fund – providing support for regions dependent on fossil fuels, including coal-mining regions (Warwas, 2025; Dziembała et al., 2025).

The impact of the twin transition on regional development is also *evident*. Regions with well-developed digital skills, ICT infrastructure and innovative capabilities are developing green technologies and more efficient economic models more rapidly; in other words, the synergies between the two dimensions of the twin transition can help drive regional competitiveness (Santoalha et al., 2021). Research shows that digital skills are a factor enabling green diversification, particularly when more complex environmental technologies are considered (Bürscher et al., 2025). At the same time, it is suggested that the twin transition may exacerbate regional disparities. It favours wealthier regions, which have higher levels of innovation, better institutions and greater human capital resources (Maucorps et al., 2023a). Weaker regions, on the other hand, may fall into a ‘development trap’, and a lack of adequate digital skills may exacerbate polarisation (Caravella et al., 2023). A key factor in amplifying the effects of the twin transition is the quality of regional institutions – regions with better institutions derive greater benefits from digital and green investments (Bănică et al., 2024). The European Commission recognises smart specialisations *for sustainability* (S4) as a tool to strengthen competitive advantages, particularly important for less innovative regions. They

enable the combination of local knowledge with green and digital technologies (Panori, 2024). Digitalisation is another factor enhancing the effectiveness of the green transition. Digital technologies support emissions reduction, improved energy efficiency, the development of smart mobility, the optimisation of energy networks, and the circular economy (Komninos & Panori, 2025; Benedix et al., 2025).

3. Towards measuring regional transformational competitiveness

The growing role attributed to regions in generating economic growth, wealth and socio-economic well-being has made regional competitiveness a key reference point in the formulation of public policies: regional policy, smart specialisation, regional innovation strategies, etc. Competitiveness indices such as the Global Competitiveness Index (GCI) developed by the World Economic Forum, or the World Competitiveness Ranking prepared by the IMD World Competitiveness Centre, have begun to be used to assess competitiveness at national and sub-national levels. Since 2010, the RCI, based on the GCI, has measured the key competitiveness factors of all NUTS-2 regions across the European Union. Using a comprehensive set of indicators, the index measures a region's ability to offer attractive living and working conditions for businesses and residents. The fifth edition of the index, published in 2022, is based on an updated methodology and is therefore named RCI 2.0. Regional competitiveness, as understood in the RCI as a region's ability to offer an attractive and sustainable environment for businesses and residents in which they can live and work; therefore, it also takes environmental issues into account. The concept of sustainable development here refers to a region's ability to provide an attractive environment in both the short and long term. In the latest edition, the RCI comprises 68 indicators grouped into three sub-indices – 'Core', 'Efficiency' and 'Innovation' – and 11 pillars describing various aspects of competitiveness (Dijkstra et al., 2023). The level of regional competitiveness as expressed by the RCI is shown in Figure 1.

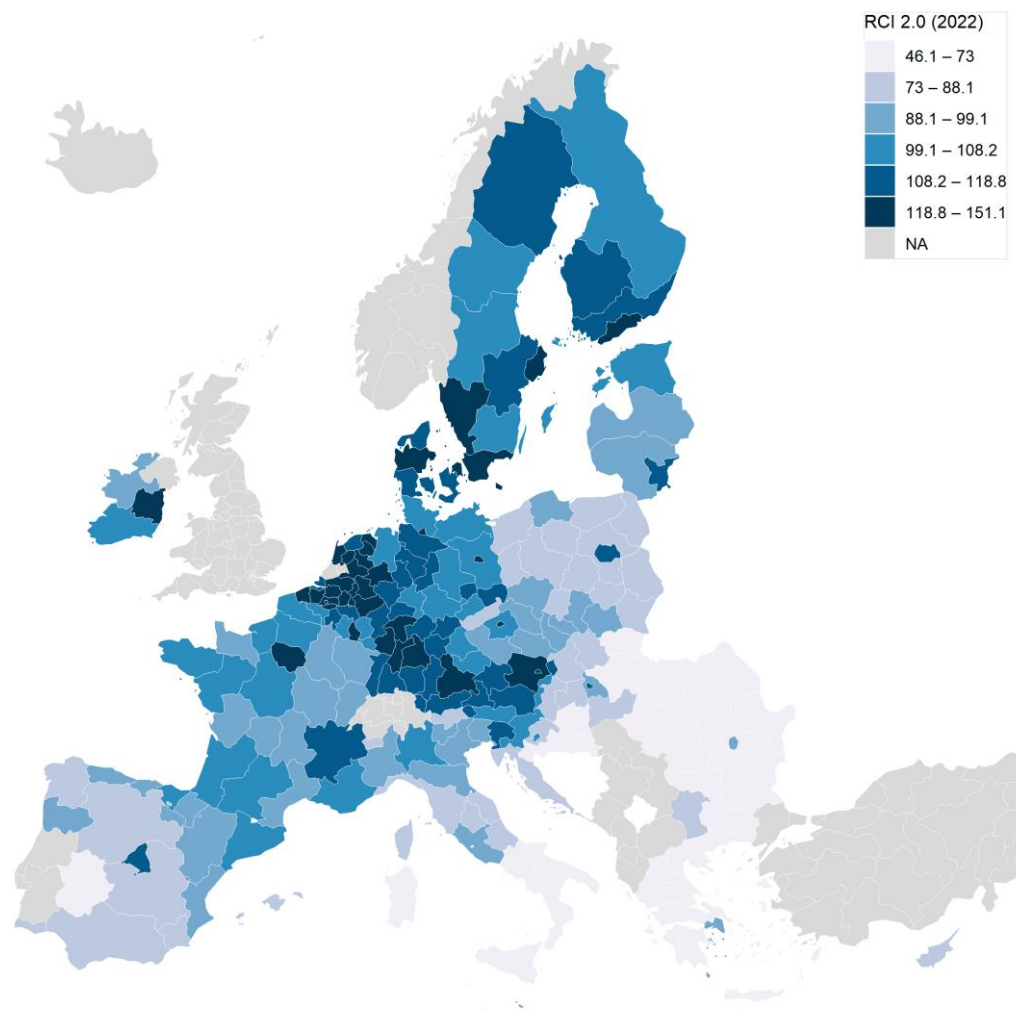


Figure 1. EU Regional Competitiveness Index

Source: own compilation based on (European Commission, 2023).

The current approach to regional competitiveness, operationalised through the RCI 2.0 among other measures, is no longer sufficient in the context of the ongoing economic transformation. Although this index accounts for elements of long-term development potential, its design does not fully capture the dynamics of the transformational processes associated with the so-called ‘twin transition’. Based on the methodology used to construct RCI 2.0, it can be argued that its construct is currently incomplete, as it has a limited capacity to capture rapid structural changes (European Commission, 2023). At the same time, the literature emphasises that the green and digital transitions are central to the EU’s contemporary development model, redefining the conditions for regional competitiveness. According to Barbero et al. (2025), the twin transition is a hallmark of the new growth strategy. This means that competitiveness cannot be analysed solely through the prism of current economic performance, but should take into account regions’ capacity for adaptation and structural transformation. Furthermore, research

indicates that transformation processes are highly spatially heterogeneous in nature and may lead to a widening of regional disparities (Maucorps et al., 2023b). Regional competitiveness should therefore also be considered in the context of regions' capacity to participate in the transformation and to mitigate its negative distributional effects. In this context, the perspective of transformational competitiveness is becoming increasingly important, integrating both the ability to compete in global markets and the transition towards a low-carbon and digital economy. As recent research indicates, these processes simultaneously encompass 'structural change and industrial transition' linked to competitiveness and the decarbonisation of the economy (Santos and Conte, 2025). Consequently, it can be argued that the existing RCI-based approach needs to be expanded to include a transformational dimension, encompassing regions' ability to adapt to the challenges of the green and digital transition, as well as their resilience to the resulting development inequalities.

4. Research strategy

The aim of the analysis was to construct a composite indicator that describes regions' ability to function under conditions of the green and digital transition (twin transition). The starting point for the adopted methodology was the approach developed in the work of the Joint Research Centre (JRC), in particular regarding the measurement of regional resilience and the construction of composite indicators, which emphasises the need to integrate various dimensions of socio-economic development into a single coherent analytical measure (Kostarakos et al., 2025; Nardo et al., 2005). In line with this approach, regional development should not be analysed solely through the prism of current economic performance but also through the capacity to adapt to long-term structural changes, such as climate change and digital transformation. This perspective is consistent with the broader literature on resilience, which emphasises the importance of regional systems' capacity to absorb shocks, adapt and transform in response to changing conditions (Boschma, 2015; Martin, 2012).

The analysis was conducted at the NUTS 2 regional level and based on five variables reflecting key aspects of the green and digital transitions. The selection of variables (Table 2) was informed by previous research in this field (Kostarakos et al., 2025; Royuela et al., 2026).

Table 2. Variables selected for the construction of the indicator

Name	Explanation	Dimension	Source
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GHG	Greenhouse gas emissions in tonnes of CO ₂ per 1,000 inhabitants (2022)	Vulnerability	ARDECO [EDGARP]
Empl_in_BS	Proportion of employees in high-emission sectors [A-E] (2022)	Vulnerability	Eurostat
Cool_Heat	Cooling and heating degree days (2022)	Exposure	Eurostat
Change_CO2	Change in CO ₂ emissions: defined as the long-term difference (1990–2022) in per capita CO ₂ emissions from fossil fuels	Readiness	ARDECO [EDGARP]
Empl_circ_econ	Employment in circular economy sectors per 100,000 inhabitants	Readiness	(Royuela & López-Tamayo, 2025)

Source: own compilation.

The selection of variables was based on their ability to capture both the structural conditions of the regional economy and its susceptibility to transformational processes, which is consistent with the OECD (2017) approach used to measure structural transformation and green growth. In the first stage of the analysis, the variables were classified into stimulants and disincentives. Variables whose higher values indicate greater transformation risk, such as greenhouse gas emissions, employment in high-emission sectors, and cooling and heating degree days, were classified as stimulants describing transformation susceptibility. Conversely, for the dimension of transformational readiness, employment in circular economy sectors was classified as a stimulant, whilst changes in CO₂ emissions were classified as a destimulant (emissions are falling – the region is decarbonising). This classification is consistent with the approach used in the construction of resilience indicators, where a distinction is made between factors that increase the system's vulnerability and those that strengthen its adaptive capacity (Cutter et al., 2008).

To ensure the comparability of variables, min-max normalisation was applied, transforming each variable to a common scale from 0 to 1. The normalised variables were then grouped into two main analytical dimensions, corresponding to the concept of regional system resilience: the vulnerability dimension and the adaptability-readiness dimension, as shown in Table 1. For each of these dimensions, a sub-index was calculated by aggregating the variables using the geometric mean, which is the standard approach when there are no clear theoretical grounds to differentiate the significance of individual components (OECD, 2008).

In the next step, a composite indicator (Twin Capacity) was constructed through the geometric aggregation of the sub-indicators using equal weights, in accordance with the following formula (Kostarakos et al., 2025):

$$Index\ TC_r^j = Vulnerability_r^{Wp} * (1 - Preparedness_r)^{Wr}$$

where r denotes the region, j denotes the dimension of transformation under analysis, and w_p and w_r denote the weights assigned to individual components. It should be noted that the weights are equal and their sum is one. As the equation shows, an increase in vulnerability is associated with a rise in the TC index value, whilst a higher level of preparedness counteracts these negative effects. Consequently, the index is an aggregate measure of regions' vulnerability to transformation-related challenges (higher value = greater transformation risk). To ensure an intuitive interpretation, a conversion was applied that changed the sign of the index (Twin Capacity = $-$ Twin Risk), so that higher values denote greater transformation capacity of the region. Such transformations are standard practice in the construction of composite indices (OECD, 2008), whilst the interpretation itself in terms of vulnerability and adaptive capacity is consistent with the literature on regional resilience (Cutter et al., 2008; Martin & Sunley, 2015). The method used is exploratory in nature and has certain limitations, such as the selection of variables being constrained by data availability, the assumption of equal weights, and the sensitivity of the results to the normalisation method employed. Nevertheless, it allows for a synthetic overview of complex transformational processes and forms part of the growing body of research on the resilience and adaptability of regions in the context of profound structural changes in the economy.

5. Results

The analysis utilised a synthetic indicator of transformational capacity defined as: Twin Capacity = $-$ Twin Risk. This indicator measures a region's capacity to cope with transformational challenges. Higher values indicate greater adaptability, whilst lower values point to higher transformational risk and greater vulnerability of the region. This indicator was compared with the level of regional competitiveness measured using RCI 2.0. The analysis covered NUTS 2 regions, omitting observations with missing data².

² The RCI 2.0 index comprises eight aggregated regions (so-called commuting zones), which is why missing values for the corresponding NUTS 2 regions in 2024 were estimated using data from the *Regional Innovation Scoreboard* (RIS). In the first stage, a ridge regression model was applied, in which the RCI was explained by the RIS indicator, and values for the missing regions were then determined. In the second stage, the results were calibrated so that the weighted average (by population) corresponded to the RCI values for the aggregated regions.

In the first stage, an analysis of the linear relationship between the indicators under study was conducted. The Pearson correlation coefficient was $r = 0.019$, indicating no significant linear relationship between regional competitiveness and adaptability. To account for potential non-linear relationships, Spearman's rank correlation coefficient was calculated, yielding $\rho = 0.084$. In this case too, the value obtained indicates a very weak monotonic relationship, which is of no significant analytical importance. These relationships are presented in the graph

The results illustrated in Figure 2 lead to significant conclusions. The lack of a clear relationship between competitiveness and adaptability suggests that these two dimensions of regional development are largely independent. This means that a high level of competitiveness does not automatically imply a high capacity for adaptation in the context of green and digital transformation. Regions may perform well in traditional competitiveness rankings whilst remaining vulnerable to the structural changes resulting from the transition.

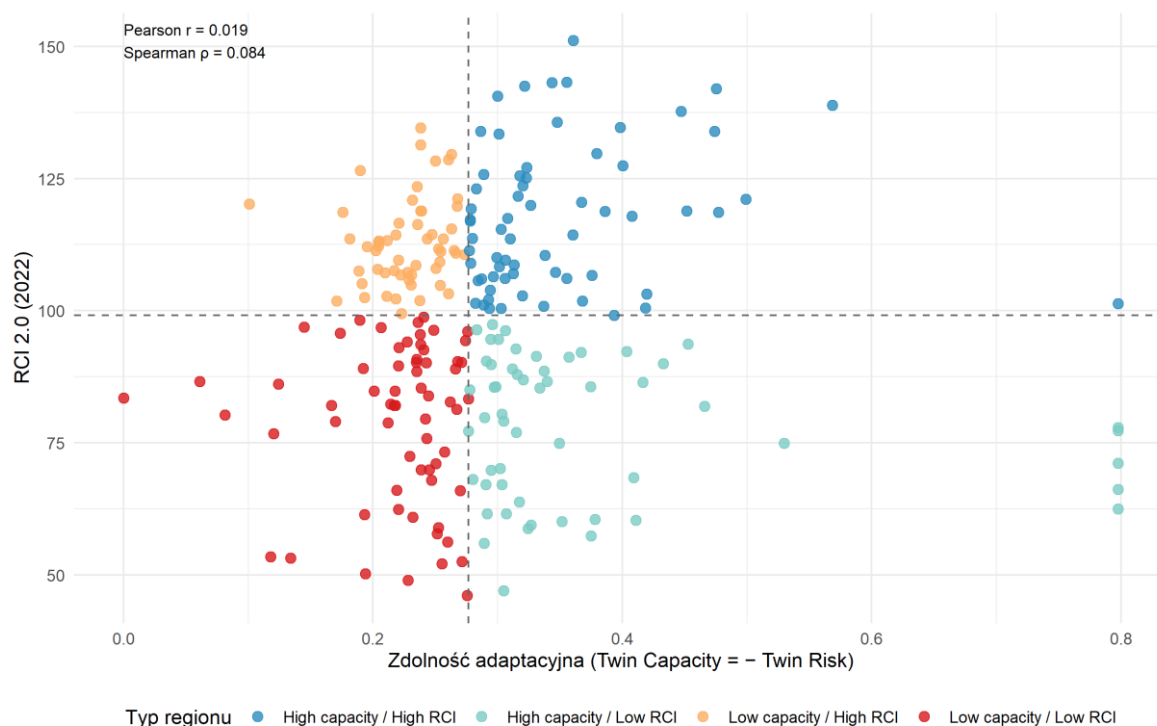


Figure 2. Relationship between transformational capacity and RCI 2.0

Source: own analysis.

In this context, regional competitiveness should be viewed as a broader concept encompassing not only current and traditionally understood economic efficiency and social welfare, but also the capacity for long-term adaptation. Regions with higher Twin Capacity Index values, and thus characterised by lower transformation risk, are better prepared to operate in a changing economic environment.

Regions with high current competitiveness often show low adaptability to the green/twin transition because their strengths are typically rooted in carbon- and capital-intensive specialisations, and transition efforts in these settings tend to "renew" or "upgrade" the existing industrial trajectory rather than build genuinely new green paths (Dawlin et al., 2025). Diversification research shows this pattern is reinforced by relatedness: strong, specialised regions diversify into activities close to what they already do, which narrows the pool of green opportunities available compared to more technologically distant reinvention (Grillitsch & Hansen, 2019). A useful refinement separates regional exposure into vulnerability, preparedness, and responsiveness, showing that competitive regions often score well on resources and vulnerability management but poorly on the capacity to phase in genuinely new activities (Baumgartinger-Seiringer et al., 2025). This can be compounded by a form of "territorial myopia", where policy attention and institutional capital gravitate toward defending near-term competitiveness metrics at the expense of transition-oriented investment. Left unaddressed, this uneven preparedness risks producing new pockets of "green discontent" even in regions that appear economically strong by conventional indicators (Rodríguez-Pose & Bartalucci, 2024). Nevertheless, the explanatory mechanisms of interlinkages between competitiveness and adaptability require further investigation.

To deepen the analysis, a typology of regions was developed by dividing them according to the medians of both indicators. Four basic groups of regions were identified. The first group comprises regions with high competitiveness and high adaptability, which can be regarded as leaders of the transformation. The second group comprises regions with high adaptability but lower competitiveness, suggesting their potential for future development. A particularly significant category comprises regions with high competitiveness but low adaptability. These areas may face significant barriers to future transformation, despite their current strong economic conditions. The final group comprises regions with low competitiveness and low adaptability, requiring comprehensive structural support. The typology of these regions is shown in Figure 3.

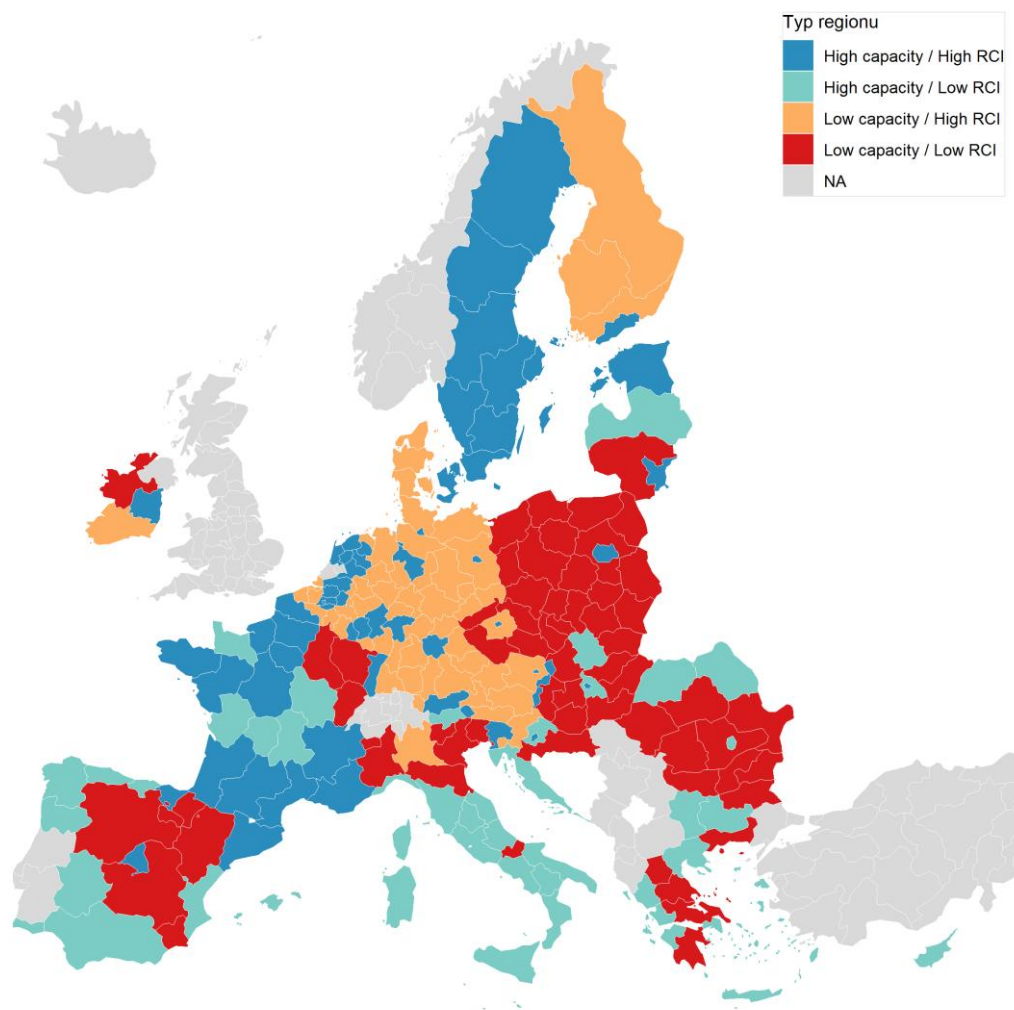


Figure 3. Typology of NUTS 2 regions by adaptability and competitiveness

Source: own analysis.

The results of the analysis have significant implications for regional policy. They point to the need to move away from an approach that treats competitiveness as the dominant measure of a region's attractiveness. Instead, the adaptive capacity of regions should be taken into account, as it is a key factor in determining their long-term development trajectory in the context of the twin transition.

In summary, the analysis indicates that regional competitiveness should be reinterpreted to incorporate an adaptive dimension. In the context of the green and digital transitions, it is precisely the ability to adapt to change—and not merely the provision of an attractive and sustainable environment for businesses to operate and for residents to live and work—that constitutes a key element of sustainable regional development.

6. Summary

The approach to defining regional competitiveness used to date is based on a region's ability to achieve sustainable economic development whilst attracting resources (capital, labour, technology) and maintaining a high standard of living for its residents. It does not capture regions' adaptive capacity to meet the challenges associated with ongoing structural changes. Therefore, the proposed approach assumes the need to reinterpret this concept, taking into account regions' adaptive capacity to current challenges. The aim of this analysis was, in addition to a critical review of existing approaches to measuring regional competitiveness, to examine the relationship between regional competitiveness and regions' ability to adapt in the context of the green and digital transition (*twin transition*). Numerous studies and reports confirm both the existence of strong synergies between the green and digital transitions and their impact on regional competitiveness. The twin transition can strengthen regional competitiveness by boosting productivity through the digitalisation of processes, creating new pathways for technological specialisation, attracting capital investment in advanced industries, and supporting job creation in innovative sectors. It also carries the risk of widening the gap between leading and lagging regions; it depends on the quality of institutions and infrastructure and may give rise to 'digital optimism' that fails to account for environmental costs (Horn, Felt, 2026). Appropriately targeted public interventions are particularly important for regions with high competitiveness but low transformational readiness, which may face a structural crisis in the future. The research findings are part of the broader body of research on regional *resilience* and confirm that the twin transition poses a significant challenge to the EU's territorial cohesion, particularly if public policies fail to account for the varying adaptive potential of individual territorial units.

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