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Regional vulnerability to the green transition

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Regional vulnerability to the green transition

by

Andrés Rodríguez-Pose* and **Federico Bartalucci***

Abstract: The impacts of climate change are unevenly distributed across territories. Less is known about the potential effects of climate policies aimed at mitigating the negative consequences of climate change, while transitioning economies towards low-carbon standards. This paper presents an analytical framework for identifying and assessing the regional impacts of the green transition. We develop a Regional Green Transition Vulnerability Index, a composite measure of the regional vulnerability of European regions to the socio-economic reconfigurations prompted by the green transition. The index brings to light strong regional variations in vulnerability, with less developed, peri-urban, and rural regions in Southern and Eastern Europe more exposed to the foreseeable changes brought about by the green transition. We also draw attention to the potential rise of pockets of growing 'green' discontent, especially if the green transition contributes, as is likely to be the case, to leaving already left-behind regions further behind.

Keywords: Green transition, environment, left-behind regions, development trap, European Union

JEL classification: O44, Q56, R11

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1. Introduction

Climate change and environmental degradation are two of the existential challenges of the 21st century. Climate change and the associated rise of greenhouse gas emissions —if unchecked— will cause irreversible damage to our planet's weather and climate systems, leading to ever-more frequent adverse weather events (IPCC, 2022). They will also have profound consequences for future living conditions across the planet. Although climate activists and experts have voiced criticism about the dragging of feet in the adoption of climate change mitigation policies, international organisations and many countries have woken up to the climate emergency. The European Union (EU) is leading the way in this 'green transition'. In 2020, it adopted the European Green Deal, an all-encompassing set of policy initiatives aimed at (i) achieving no net greenhouse gas emissions by 2050; and (ii) accelerating economic growth decoupled from resource use (European Commission, 2019). This, together with the limits foreseen by the 2015 Paris Agreement, will reduce the progression of climate change and its negative effects (IPCC, 2022).

It is commonly understood that the challenges of climate change are borderless and affect different places in diverse ways. Developed countries —and, in particular, countries in the EU— are leading the reaction and the transition to greener, low-carbon economies and societies. Their greater awareness of climate-related risks, financial muscle, and stronger institutions relative to most other parts of the world put them in a strong position to adopt the radical and often painful measures necessary to combat climate change (McCann & Soete, 2020). However, the costs of implementing the green transition are not evenly spread. Research has been pointing for some time that the economic pain can become concentrated in the already economically fragile areas of developed countries and in the developing world (Marino & Ribot, 2012; Ramos-Castillo et al., 2017).

Despite these well-understood general facts, a critique that is often directed at existing analyses of the green transition is the absence of a context, which may lead to the erroneous conclusion that sustainability can take place anywhere through similar processes (Coenen et al., 2012). Relatedly, there have been growing calls to adopt a spatial analytical lens to the study of sustainability transitions for two reasons. First, transitions are usually localised processes occurring in multi-scalar and networked contexts, and place-specific and contextual factors often shape how transitions unfold in various territories (Coenen et al., 2012; Binz et al., 2020). In this regard, pre-existing industrial specialisation is a crucial factor influencing the development of new green industries (Grillitsch & Hansen, 2019). Approaches in this respect have already started to emerge in the policy-making arena. The updated 2020 EU Industrial Strategy, for instance, has outlined a blueprint for implementing transition pathways across various priority industrial ecosystems such as construction, tourism, mobility, and energy-intensive production (European Commission, 2022a). Second, place sensitivity in analysing green growth and transition can aid policymakers with the transferability of findings for the development of more successful regional development strategies (Coenen et al., 2012). This could lead to implementing policy mixes integrating the multiplicity of infrastructure, consumption and production activities that constitute places (Konrad et al., 2008; Murphy and Carmody, 2019). The cross-fertilisation between transition studies and economic geography has therefore become extremely topical.

Within the climate change literature, the inequality discourse is typically linked to the costs of inaction to combat climate change and its associated inequality-enhancing effects on the already underprivileged (Klinsky et al., 2016; Markkanen & Anger-Kraavi, 2019). However, little has been said about the possible negative externalities of green transition policies, such as those aimed at reducing greenhouse gas emissions. These policies are, nevertheless, set to reshape productive sectors, from food to energy, manufacturing, housing, and mobility (Henderson et al., 2020). They will also create opportunities by driving world-class capabilities in the inception, design, production, and distribution of sustainable and green technologies[1] (European Commission, 2020a).

The changes prompted by large-scale climate change interventions, such as the European Green Deal, will not be territorially evenly spread. Following the implementation of the Green Deal, Europe will undergo a radical reconfiguration of production and consumption activities

[1] We use the term 'green technologies' to refer to technologies designed to reduce pressure on natural resources and improve adaptation to the changing environment. They encompass a broad spectrum of domains, including environmental management, energy production, water management, capture and storage of greenhouse gases, transportation, buildings, waste treatment, and management and production of goods (Moreno & Ocampo-Corrales, 2022).

(Stokes, 2016). Some places will tap into the opportunities offered by regional diversification and specialization in the green economy. Others —often plagued by pre-existing economic, social, and institutional bottlenecks—, will, in contrast, fall further behind (McCann & Soete, 2020; Moreno & Ocampo-Corrales, 2022).

A potential concentration of the costs in vulnerable regions can have detrimental effects on social cohesion, exacerbating what is an already galloping discontent (Dijkstra et al., 2020), and, ultimately, jeopardizing the successful implementation of green policies. If left unchecked, the breakdown of social cohesion and discontent may enhance the support for parties with clear climate-change-sceptic positions, frequently located at the extreme right-wing of the political spectrum (Martin & Islar, 2021). Already, the introduction of what are often perceived as top-down climate mitigation policies has triggered angry reactions: a diesel tax was the spark that lit the fire of the *gilet jaunes* movement in France (Bourdin & Torre, 2022). If carbon taxes, for example, were to hit more vulnerable territories harder, there could be a renewed revenge of the so-called *places that don't matter*, places where people feel hard done by a green transition they perceive as imposed upon them and done, first and foremost, by and for the citizens of the most dynamic regions (Carattini et al., 2019; Bourdin & Torre, 2021).

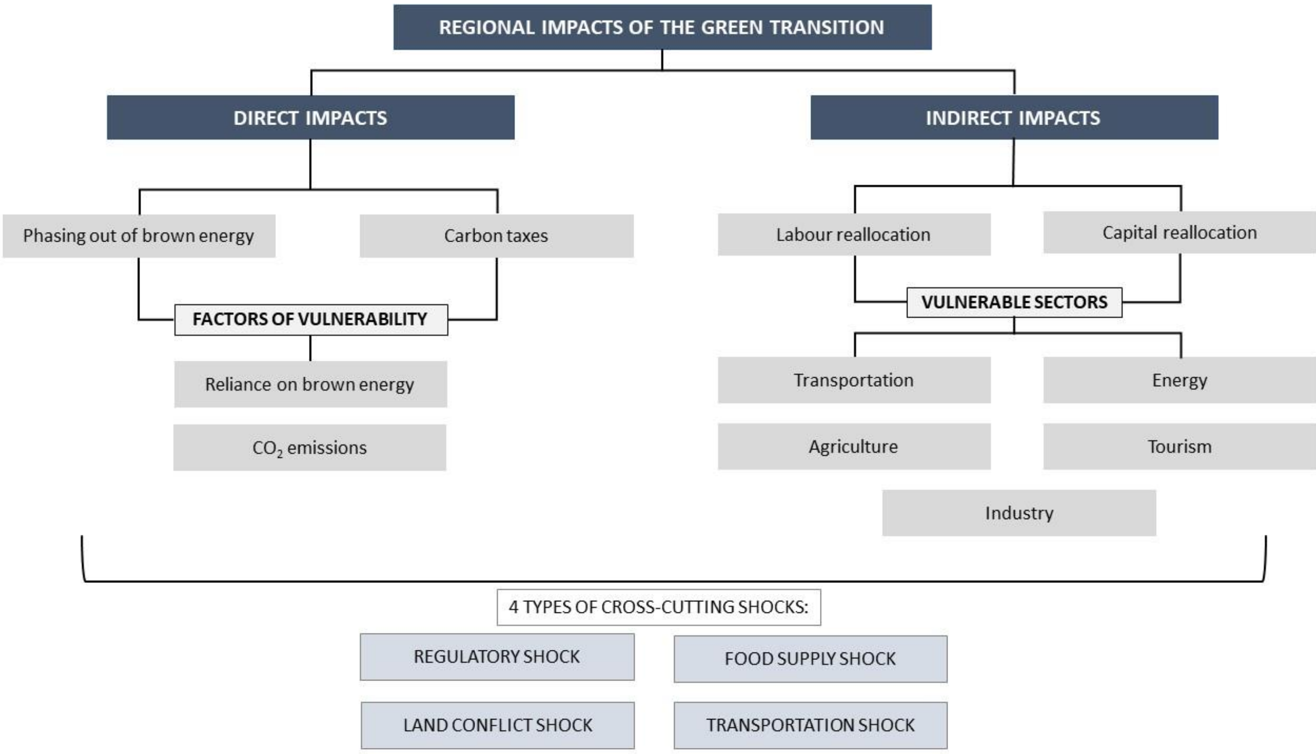
This paper delves into the interplay between regional inequalities and the implementation of the green transition and answers calls for additional research to unravel the mechanisms of this interaction (Köhler et al., 2019: Markkanen & Anger-Kraavi, 2019). It does so by presenting an analytical framework for the assessment of the regional impacts prompted by the green transition and by developing an index —the Regional Green Transition Vulnerability index— mapping those regions with the highest exposure to climate mitigation measures. Finally, the paper discusses the potential consequences of growing discontent in the most vulnerable regions and what that might mean for the green transition. The paper aims to improve existing knowledge on the link between spatial cohesion and climate policy, stressing the policy implications needed to ensure that the potential benefits of the green transition reach everyone, wherever they live and that its costs do not derail the necessary implementation of measures needed to address one of the most important problems of our time.

2. Identifying the regional impacts of the green transition

The green transition is taking place in an already polarized regional scenario. After the 2007-2008 crisis and its Great Recession aftermath, regional economic convergence has followed different trajectories in the EU. While some central European countries —and, most notably, Poland— have steamed ahead, many areas of southern Europe and old industrial regions have stagnated and fallen further behind. Gaps between large cities and rural areas have also widened in most countries (OECD, 2022). This economic stagnation and the resulting divergence may constitute a real threat to economic progress and cohesion across Europe (Iammarino et al., 2019). Many European regions have become development trapped, that is they are underperforming relative to their peers and to themselves in the past (Diemer et al., 2022). And this entrapment is happening not just at low-income levels, but also at high and medium ones (Iammarino et al., 2020; European Commission, 2022b). For instance, several regions with a low GDP per head in Italy (e.g., Calabria) and Greece (e.g., East Macedonia and Thrace and Western Greece), despite considerable support from the EU Cohesion funds, have failed to sustain long-term growth. This trend can be reconciled with economic theories of regional backwardness and circular causation, according to which already high-income regions tend to develop faster at the expenses of weaker and poorer regions due to backwash effects (Myrdal, 1957). That said, a wider group of underperforming, development-trapped regions includes regions with slightly below-average EU GDP levels, including other regions in the Italian Mezzogiorno, Portugal, Greece, and Cyprus, but also in more developed countries, such as Belgium and France. Finally, a growing number of regions with above-average GDP per head have stagnated economically, if not declined. These regions, often located in North Italy, central France, and continental Denmark, remain relatively prosperous despite their decay (Diemer et al., 2022).

The green transition may reinforce and accelerate these trends across the EU. As a multi-sector and cross-dimensional phenomenon (Henderson, et al., 2020), it is set to act upon several cross-sectoral levers to mitigate the negative implications of climate change. But these cross-sectoral levers will have differentiated impacts across regions (Stokes, 2016). It is, therefore, necessary to define a framework for the assessment and identification of the variety of regional impacts of the green transition. This section proposes an analytical framework to identify the different nature of the regional direct and indirect impacts of the green transition, focusing on vulnerability factors of regional economies. The framework proposed can be schematically represented as in Figure 1.

Figure 1. Schematic representation of the theoretical framework for the identification and assessment of the regional impacts of the green transition.



Direct impacts

First, the green transition is bound to have more direct impacts in those regions where 'brown' energy production concentrates, for both European and international markets (JRC, 2018). Brown energy —and especially coal— was for long the dominant source of energy. Despite a steep decline in the use of coal, in 2018 coal accounted for 16 percent of the EU's gross inland energy consumption and 24 percent of its power generation mix (JRC, 2018). In that year six European countries still relied on coal to meet at least 20 percent of their energy demand (Eurostat, 2019). With the adoption of the European Green Deal, the role of coal will diminish rapidly in an attempt to reduce greenhouse gas emissions. Far stricter emission requirements and restrictions on coal eligibility for energy generation are intended to achieve a more diversified energy mix. In parallel, the Renewable Energy Directive has established binding targets: by 2030 the EU should produce at least 32 percent of its energy from renewables. with a clause for a possible upwards revision (European Commission, 2018).

The imperative of the phasing out of coal contrasts with the current dependence of certain European regions on coal production. 103 European (NUTS2) regions host, at least, one coal-fired power plant, while coal mines still operate in 41 regions (JRC, 2018). The coal sector directly employs around 240,000 workers, with an additional 215,000 jobs depending on the coal value chain (JRC, 2018). Most of the coal and other green transition direct job losses are expected to occur in already lagging-behind regions, such as Upper Silesia in Poland, South-West Oltenia in Romania, and Severozapad (Northwest) in the Czech Republic (JRC, 2018). In Upper Silesia alone this may imply a loss of up to 41,000 jobs (JRC, 2018).

Additionally, the phasing out of coal and other highly polluting energy sources may contribute to exacerbate socio-economic bottlenecks in coal producing or dependent regions. Regional economies with coal power plants and coal mines tend to be below their national peers in terms of GDP per capita (JRC, 2018). Some coal-dependent regions also display high unemployment rates, such as West Macedonia in Greece. Here, an additional 3.5 percent employment loss linked to the transition away from brown energy will put pressure on a region where unemployment rates have hovered above 30 percent for the last decade and where the GDP per capita level is only 75 percent that of the Greek average (Eurostat, 2022).

Many lagging regions are thus not only more vulnerable to the negative externalities of climate change, but also more exposed to the direct negative effects of the European Green Deal (European Union, 2017; OECD, 2019). The negative externalities will be particularly harsh in lagging regions still dependent on coal.

On top of the phasing out of coal, carbon taxes —another key pillar of the green transition— will also have differential impacts across regions. Past research has underlined that the costs of carbon taxes are not equally distributed across individuals and places (Romer & Romer, 2010; Känzig, 2021). Carbon taxation barely affects the expenditure of high-income households. Their falls in purchasing power are only marginal. For low-income households, the story is different, as they suffer a much larger fall in shares of disposable income. The twin challenges of higher energy bills and reduction in income linked to working in sectors more exposed to carbon pricing will squeeze incomes at the bottom of the pyramid. Many vulnerable high-carbon-intensity regions will see a reduction of production and loss of competitive advantage (Känzig, 2021). Regions with carbon-intensive economies will endure the bulk of the additional costs and price increases stemming from the introduction of carbon taxes. Carbon taxes are a powerful tool to raise the opportunity cost of creating pollution and developing carbon-intensive industries, meaning that high-carbon-intensity regions will witness steep price surges in goods and services (del Guayo & Cuesta, 2022).

Indirect impacts

Even more impactful than the direct effects of the implementation of green transition for economic dynamism across EU regions are a range of indirect effects. The indirect impacts of the European Green Deal will stem from increased factor mobility and the reallocation of economic and social assets, which may follow the likely concentration of green technologies, employment, and innovation in regions and cities with more suitable endowments for the absorption of capital and labour directed towards sustainable economic activities (Atkinson et al., 2019).

Research has pointed to the relevance of skilled migration in the context of the emergence of skill-biased technological changes, such as the digital and green transition (Diamond, 2016; Giannone, 2017). Regional specialisation in green technologies and sustainable economic activities requires a qualified enough workforce, specialisation in related economic fields, and adequate infrastructure and facilities (Moreno & Ocampo-Corrales, 2022). The *a priori* more limited ability of many left- and lagging-behind regions to tap into the opportunities offered by the development and production of green technologies, such as renewables, can result in loss of employment and a mismatch between the labour force skills level and demand within the local economy, generating dissatisfaction and, possibly, brain drain (Fratesi & Rodríguez-Pose, 2016). Brain drain may, as in the past, contribute to downward economic spirals, depressing human capital investment, and triggering negative demonstration effects. Such a process, may, in turn, push the best and brightest to either leave to acquire —or immediately after acquiring— a higher education degree or to abandon high level education altogether (Brzozowski, 2007). Already vulnerable regions may thus find themselves deprived of their prime human capital. The adoption of climate mitigation policies and cutting-edge green technologies may, as a consequence, generate social problems in lagging- and left-behind regions.

The concentration of opportunities and know-how in more prosperous areas associated to the green transition can accelerate the pace of skilled migration from left-behind and vulnerable regions, especially at the higher echelons of the skill ladder. As the most skilled flock towards leading metropolitan areas, left-behind areas will be increasingly left with stocks of lower-skilled workers and lower-productivity firms (Farole et al., 2018). The result will not just be an increase in regional divergence, but also growing discontent in what already are highly internally polarized societies. Green-transition-related brain drain can thus be at the root of self-reinforcing effects, deepening pre-existing territorial divides. A declining population —especially if skilled— frequently results in a mismatch between the supply and demand of services, which become underutilized, poorly maintained, and, at times, inviable. The loss of skills and talent, furthermore, can negatively affect local and regional innovation systems —which in low-performing regions are already laced with deficiencies. The decline in local skilled workers will reduce the productivity of small and medium-sized enterprises (Tietjen & Jørgensen, 2016). Such a loss of talent can be particularly acute in rural and vulnerable regions, which depend more on small- and medium-size firms (SMEs) —SMEs employment represents around 38 percent of the total in these regions versus 27 percent in urban areas (ESPON, 2020). Many of these SMEs will also suffer from skills shortages.

Finally, the green transition may redirect capital investments towards regions and cities where pre-conditions in terms of infrastructure, skills, and governance are more favourable. Metropolitan areas are already the main investment targets for climate mitigation policies (CPI, 2021). These investments include both interventions on the built environment and innovation policies aimed at accelerating specialization in sustainable economic activities (European Commission & UN Habitat, 2016). Currently, cities are responsible for around 70 percent of all green action plans. Their higher innovation potential, including a higher and better-trained stock of human capital and better infrastructure and institutions (Barbieri et al., 2021), put them on the starting blocks to respond and adapt to climate change intervention. National governments also have incentives to focus on cities when implementing climate mitigation policies (Hammer et al., 2011). Cities are responsible for two thirds of global energy consumption and generate around 70 percent of greenhouse emissions (OECD, 2019). Heating and air conditioning systems contribute around 7 percent of global emissions (Henderson et al., 2020). Cities and urban areas account for most emissions, but they are also the places where most investment related to the green transition takes place. Across the EU, metropolitan areas account for 55 percent of expenditure and 64 percent of public investment in climate and environmental actions (OECD, 2019). The concentration of green investment in urban areas is explained by its higher returns. The high urbanization rate of Europe, with almost 75 percent of the total population living in urban areas, implies that urban-focused policy actions aimed at fostering sustainable growth can potentially achieve far higher returns than if resources are targeted to more sparsely populated rural areas, towns, and small cities (World Bank, 2022c).

Capital mobility and the targeting of green capital towards European urban areas can also be explained by favourable ex-ante conditions, such as the presence of strong innovation-led economies capable of generating widespread local knowledge spillovers (McCann & Soete, 2022). Cities and metropolitan areas with dynamic knowledge economies and social and economic infrastructure are ideally placed to adapt to the Green Deal. Large cities also tend to host the best universities. This facilitates the connection to global knowledge and scientific networks (McCann & Soete, 2022). They also possess significant lobbying potential to negotiate with green technology providers on an equal footing, and they have media and brand profiles, which place them under the scrutiny of the wider public (European Commission & UN Habitat, 2016). This is particularly so in capital cities. Moreover, the higher concentration of talent creates fertile grounds for the development and diffusion of green technologies in cities (McCann & Soete, 2022).

The rationale behind concentrating capital investments in green technologies and climate mitigation in the more dynamic regions is driven by the idea that agglomeration economies and the link between city size and productivity, innovativeness, and entrepreneurship (Glaeser & Kerr, 2009; De la Roca & Puga, 2017) will lead to greater returns to investment. But, while this may indeed be the case, the opposite side of the coin is unlikely to materialize: geographical trickle-down diffusion from core cities to other regions rarely happens, at least with the expected magnitude (Iammarino et al., 2019). As has been seen in other transitions, such as the digital transition, European left-behind regions have more often than not struggled to benefit from the market forces which should have led to a reallocation of economic activity to lagging- and left-behind regions. Hence, market forces, rather than alleviate within-country territorial differences, may contribute to enhance them (Iammarino et al., 2019). Based on this evidence, the high density of green capital investment in cities and urban regions will not reduce the economic and social gap. It will aggravate the underlying spatial differences in innovation, competitiveness, and economic dynamism.

Moreover, regions highly dependent on specific sectors may suffer more from the negative impacts of the green transition. The consensus is that the green transition will mainly reshape five broad sectors: energy, agri-food, manufacturing, housing, and transportation (European Commission, 2018; Henderson et al., 2020). These sectors are also the largest contributors to greenhouse gas emissions: energy industries account for 28 percent of total emissions in the EU; mobility for almost 25 percent; and agriculture for 10 percent (Eurostat, 2018). In addition to sector-wide transformations, within-sector shocks may occur based on the presence —or absence— of 'green skills', such as engineering skills for the conceptualisation and implementation of technology, and managerial skills for executing and monitoring environmental practices (Vona et al., 2018).

Overall, the green transition and the European Green Deal are set to reshape the geography of jobs and wealth across EU regions through dynamics involving labour and capital mobility and reallocation. There will be regional winners and losers. The winners will experience significant increases in capital investments in the green economy.[2] These areas will benefit from the inflow of skilled workers and talent from other regions. The losers may suffer from outflows of capital and talent to regions where conditions for the creation of jobs linked to the green economy are more favourable. Table 1 summarizes the key opportunities and threats for these two groups of regions.

[2] The green economy is defined as "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. It is low carbon, resource efficient, and socially inclusive" (UNEP, 2011: 2).

From the outset, urban and metropolitan regions may possess the right pre-conditions and specialisation —in terms of infrastructure, consumption, and production activities— considered crucial to make the most of new green industries (Capasso et al., 2019; Grillitsch & Hansen, 2019; Jakobsen et al., 2022). Hence, they have the highest odds to be the winners. This is not to say that peripheral and rural regions are destined to miss out from the implementation of the European Green Deal. There is, however, a pressing need to identify potential development paths that can allow even the weaker clubs of regional economies to benefit from the reconfigurations prompted by the green transition. For instance, remote regions have been able in the past to create dynamic regional innovation systems, especially when it comes to incremental and experimental innovations and through extra-regional linkages (Rodríguez-Pose, 1999; Eder, 2019). In addition, research has highlighted how rural areas may have an advantage when it comes to renewable energy production potential due to their availability of land (Benedek et al., 2018). Whereas this has often been confronted with local resistance, for instance when it comes to solar and wind farms, there have also been successful cases of community-owned renewable energy installations (Mühlenhoff, 2010; Benedek et al., 2018; Clausen & Rudolph, 2020). For peripheral regions, the implementation of policies that provide directionality towards the green transition by, among others, adjusting procurement and innovation initiatives, have also proven effective to drive green industry development (Grillitsch & Hansen, 2019; Finne et al., 2021). Section 4 delves into potential future scenarios and implications for vulnerable and lagging-behind regions.

A scenario where the impacts of the green transition and its associated policies are unevenly distributed across the regions of Europe needs to be developed in greater detail than hitherto. First, it becomes paramount to identify which regions may be most affected in the short- and medium-run. This implies identifying factors of vulnerability and producing measures of vulnerability capturing a region's exposure to the direct and indirect challenges prompted by the green transition. Second, there is a need to uncover correlations between the current territorial polarization across EU regions and the compounding of those disparities by the green transition. Regions which already suffer from economic stagnation and decline, and which could be vulnerable to competitiveness losses due to green policies may be at the greatest risk of falling further behind, deepening European territorial cleavages and generating serious economic, social, and political challenges.

Table 1. Opportunities and threats for winning and losing regions following the implementation of the European Green Deal.

	CAPITAL MOBILITY		LABOUR MOBILITY	
	OPPORTUNITIES	**THREATS**	**OPPORTUNITIES**	**THREATS**
WINNING (PROSPEROUS REGIONS)	Increased local public budgets for the implementation of climate change mitigation measures Increased innovation, competitiveness Increase in R&D investment	Misallocation of funds and rent-seeking behaviour from private firms Risk of capture by vested interests	Attraction of human capital and talent Availability of cheaper skilled workforce Creation and consolidation of knowledge economies Migrants as net fiscal contributors	Potential displacement of certain groups of local workers Heightened pressure on social services
LOSING (DEVELOPMENT-TRAPPED AND VULNERABLE REGIONS)	Potential of knowledge spillovers from urban to vulnerable regions	Reduction of private and public capital investments, due to budget constraints Reduced innovation potential and competitiveness, due to loss of high value-added investments Exacerbation of local, long-standing structural bottlenecks	Alleviation of unemployment pressures Potential of increased well-being and consumption through remittances Potential of attracting returning migrants and enabling technological and knowledge transfers	Demographic decline and increase in age-dependency ratio Reduction of human capital and talent Skills mismatch Erosion of tax bases and local public budgets Reduction of institutional capacity

Source: Authors' elaboration based on Brzozowski, 2007; Farole et al., 2018; JRC, 2018; Vona et al., 2018; Atkinson et al., 2019; Iammarino et al., 2019; Henderson et al., 2020; del Guayo & Cuesta, 2022; McCann & Soete, 2022; Moreno & Ocampo-Corrales, 2022.

3. Capturing regional vulnerability: the Regional Green Transition Vulnerability Index.

Methodology and data

But how can the direct and indirect, positive and negative impacts of the green transition be measured? In this section we provide a necessarily imperfect, given data constraints, empirical measure of regional vulnerability to the changes prompted by the transition to low-carbon societies and economies. We understand vulnerability in the way proposed by Adger (2006: 268): "the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt." In particular, we focus on the stresses generated by the policies currently being implemented (and that will have to be implemented) to achieve the green transition. We construct an aggregate measure of vulnerability —the Regional Green Transition Vulnerability Index— aiming to capture the multi-dimensionality of the European green transition and its effects on territories. The use of a composite index addresses the need to encompass the wide range of effects in play for both the more direct impacts and indirect effects of the transition. The resulting index focuses on the short- and medium-term effects, encapsulating the impacts of policies and transformations currently being implemented or likely to be implemented in the coming decade.[3] Composite indices are often credited for reducing the dimensionality of datasets, aiding interpretability while simultaneously limiting information loss (Joliffe & Cadima, 2016). The proposed Green Transition Vulnerability Index is rooted in the analytical framework presented above and its pillars recall the model presented in Figure 1. From a theoretical standpoint, the specification of the index builds on previous research classifying sectors and tasks according to their vulnerability to environmental regulation (see e.g., Vona et al., 2018). Whereas the resulting index incorporates an heterogenous set of variables, we argue that such a broad-brush approach is needed to assess both direct and indirect impacts, hence taking into account the multi-dimensionality of the transition. This also sets our index apart

[3] Capturing the long-term effects requires a significantly more intricate framework than the one proposed in this paper. To account for long-term impacts and net welfare outcomes for regions, it is crucial to consider the new composition of economic output, taking into account both the net effects on traditional sectors and the investments made in greener industries. Additionally, it is essential to incorporate the social and environmental impacts associated with potential risks such as climate migration and extreme weather disasters.

from other existing empirical attempts to assess regional vulnerability to the green transition (see, for instance, OECD, 2023).

The Green Transition Vulnerability Index encompasses region-specific attributes linked to six broad pillars: (i) fossil fuel dependency and emissions; (ii) tourism; (iii) energy; (iv) transportation; (v) agriculture and land use; (vi) and industry. Whereas the first and sixth pillars mostly cover the direct impacts of the green transition, the remaining pillars broadly include those sectors identified to be at greater risk of undergoing major revolutions (see e.g., European Commission, 2018; Henderson et al., 2020). Each pillar consists of several indicators, illustrated in Table 2. Each indicator is expected to be correlated with a region's vulnerability to the green transition. Considering the specification of the index, we recognize that the focus on structural regional weaknesses may provide a better estimate of the potential negative impacts of the green transition than of its possible growth-inducing effects. Appendix 1 shows descriptive statistics for all variables included in the index, together with additional details on the methodological steps adopted to construct the index. The Regional Green Transition Vulnerability Index is calculated for each region by means of Principal Component Analysis (PCA), producing a single indicator of vulnerability, while simultaneously preserving much of the original variation of its single components. More details on the calculation of the index through Principal Component Analysis can be found in Appendix 2.

Table 2. Variables included in the Green Transition Vulnerability index.

TYPE OF IMPACT	PILLAR	VARIABLE (YEAR)	SOURCE
Direct	Fossil fuels dependency	CO_2 emissions from fossil fuels per head (2018)	Crippa et al. (2019)
		Change in CO_2 emissions per head from fossil fuels between 1990 and 2018	JRC-EDGAR gridded CO2 data
		Coal transition region with at least 100 jobs in the coal industry (1 if the region is identified as transition region, 0 if not) (2022)	Joint Research Centre (2022)
	Industry	Total value of wages and salaries in mining and quarrying, as a share of GDP (2019)	Eurostat (2022)
Indirect	Agriculture and land use	Gross value added (GVA) in agriculture, relative to GDP (2019)	Eurostat (2022)
		Employment in agriculture as a share of the employed population (2019)	Eurostat (2022)
		Bovine cattle by land area (2020)	Eurostat (2022)
	Tourism	Tourist arrivals relative to GDP (2019)	Eurostat (2022)
		Touristic establishments, as a share of GDP (2019)	Eurostat (2022)
	Energy	Cooling degree days (2020)	Eurostat (2022)
	Transportation	Road freight transport (loading) (2020)	Eurostat (2022)

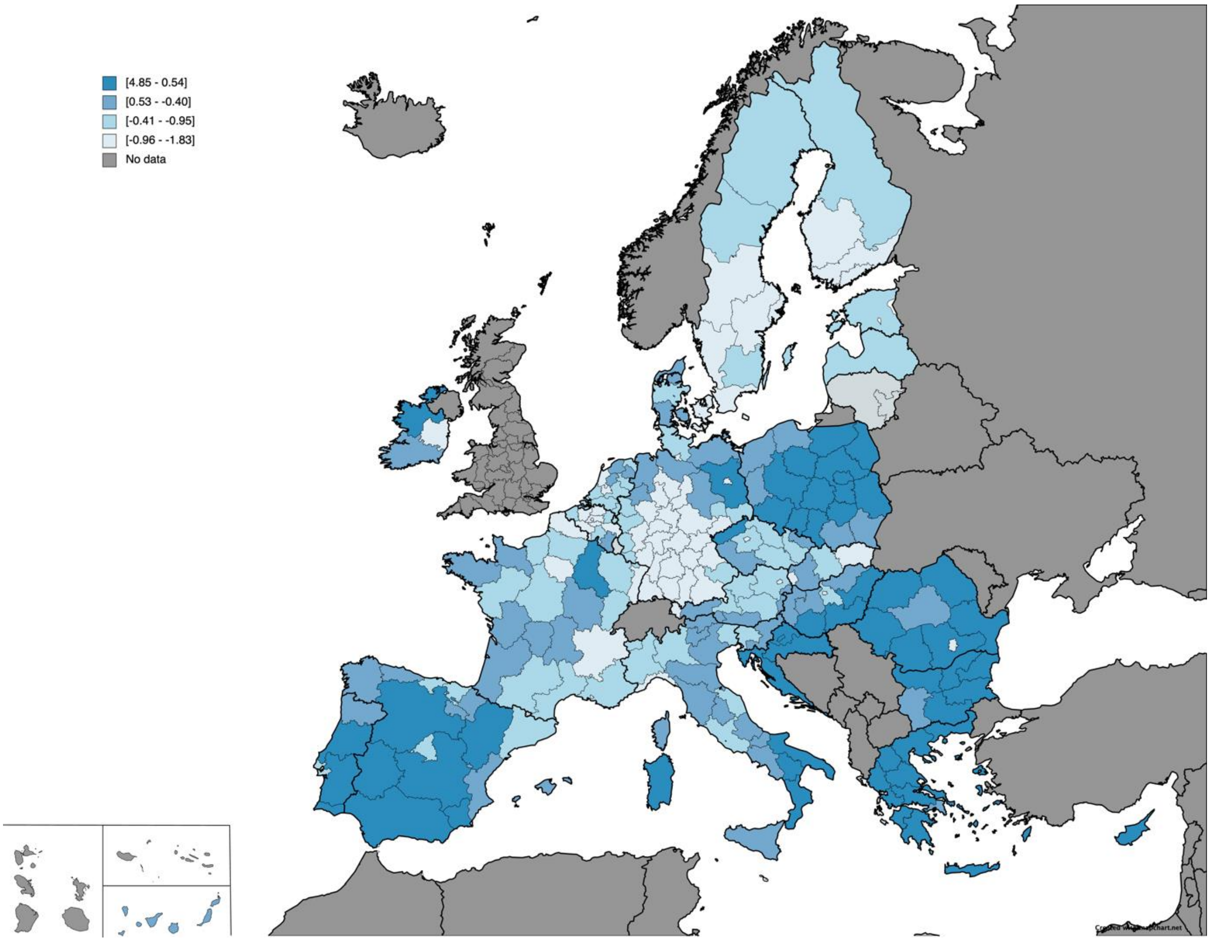
The choice of each indicator is based on the preceding theoretical discussion and data availability. First, we consider the direct effects. Highly emitting territories are more vulnerable to undergoing significant disruption in their economies due to the phasing out of brown energy and the introduction of carbon taxes and similar legislation (JRC, 2018; Känzig, 2021; del Guayo & Cuesta, 2022). For this reason, the Green Transition Vulnerability index incorporates variables such as CO_2 emissions from fossil fuels per head and whether a region is reliant on brown energy production. Also highly polluting, heavy industry —such as mining and quarrying— is, under the conditions of the European Green Deal, more likely to being scaled down, given its high contributions to CO2 emissions (European Commission, 2018).

On the more indirect front, agriculture is a highly vulnerable economic sector to the negative impacts of the green transition, given its carbon emissions and the fact that the path dependency in the sector (Knickel et al, 2009). Moreover, changes in consumer preferences —for example, shifting away from meat consumption— and the increasing drive towards the local sourcing of food, may pose challenges in territories with a high density of commercial farms (Verbeke et al., 2010). More sustainable land uses, or the need to use land to accommodate renewable energy production, may also enter into conflict with other specializations, such as tourism. There is also bound to be incompatibility between climate policies, such as the construction of wind turbines, and tourism, which is frequently proposed as a solution in lagging-behind regions in European Smart Specialisation strategies (e.g., Komninos et al., 2014; Di Cataldo et al., 2022). Research has confirmed that wind turbines are often negatively related to tourism demand (Broekel & Alfken, 2015). Heavy industry and the transportation of goods are also set to experience a considerable overhaul. Regions more dependent on road transport to move their goods and products may face steep increases in costs, as regulation on decarbonisation progresses, vis-à-vis regions relying more on rail transportation (European Commission, 2018). With this in mind, measures such as the total value of wages and salaries from mining and the volume of road freight transport are included in the index. Finally, we introduce a measure of energy demand consumption through a variable on cooling degree days. This is a weather-based technical index designed to describe the energy requirements of buildings in terms of cooling across a given year (Eurostat, 2022). While cooling accounts for a relatively small share of household electricity end-use — averaging 3 percent across the EU—, it has experienced rapid growth in recent decades. With the warming climate, cooling is set to become increasingly important (Andreou et al., 2020).

Mapping Regional Green Transition Vulnerability in Europe

The resulting index maps the contrast among European regions in terms of their vulnerability to the green transition. Figure 2 shows the quartile distribution of green transition vulnerability across NUTS2 regions in the EU. Several relevant features emerge from the map. First, metropolitan areas and capital cities are, in general, less vulnerable and more adaptable to the changes prompted by the green transition. Dublin, Bratislava, Copenhagen, Madrid, Île de France, Berlin, Bucharest, or Prague, among others, appear as substantially less vulnerable than neighbouring areas —and of their respective countries as a whole— to the green transition. Although cities generally have higher emissions levels relative to peri-urban and rural regions, they have also been more capable to reduce emissions from fossil fuels. Their structural characteristics also put large urban agglomerations in a position to withstand better the medium- and long-term direct and indirect impacts of the green transition. The lower vulnerability of cities raises questions around the rationale behind the concentration of capital investments aimed at improved adaptation to the green transition in cities. As discussed in the previous section, metropolitan areas already account for around 64 percent of public investment in climate actions across OECD countries (OECD, 2019).[4]

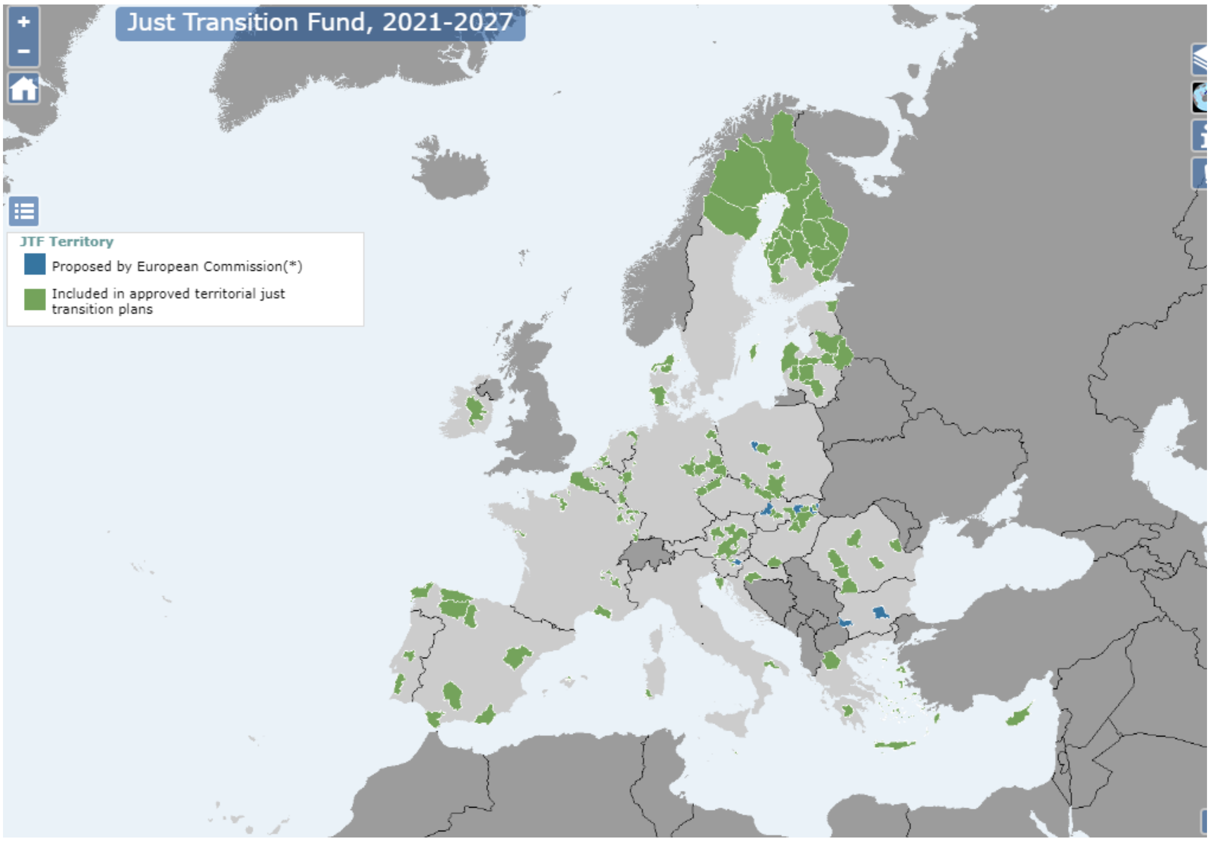
Figure 2. Regional Green Transition Vulnerability index (NUTS 2 level).



[4] To put it simply, the allocation of expenditure in climate actions is proportionate to the population distribution. Metropolitan regions, which constitute approximately 66 percent of the total population in OECD countries, account for the majority of the spending.

Second, many lagging-behind regions in Central and Eastern Europe, Southern Italy, and the Iberian Peninsula —including most less developed regions, the typology in the highest cohesion investment category of the EU— emerge as far more vulnerable to the green transition. These are regions with a considerable dependency on sectors that will be disrupted by the implementation of climate change mitigation policies, such as tourism or heavy industry, including mining and the production of brown energy. 72 percent of the coal transition regions —regions with at least 100 jobs in the coal industry— display above average scores in the index; nearly 60 percent of them are in the upper quartile. These include Bulgaria's Yugoiztochen, Greece's Peloponnesus, Spain's Castile-Leon, Sardinia in Italy, and Wielkopolskie and Dolnoslaskie in Poland. Yet only a handful of the coal transition regions have structural factors that can soften the blow of the introduction of green transition policies. Most of these are in Germany, including Düsseldorf and Cologne. Figure 3 below illustrates the vulnerable regions identified by the European Commission for funding allocation under the Just Transition Fund. This fund specifically targets regions with a heavy industry presence, taking into account factors such as industrial greenhouse gas emission intensity, high-intensity carbon sectors, and employment in sectors like coal and lignite mining, coal-fired energy, oil, cement, steel, and chemicals. It also considers the potential risks of direct and indirect job losses in these sectors. While some regions in Romania, Poland, Hungary, the Czech Republic, and Spain are identified as vulnerable by both the Just Transition Fund and the Regional Green Transition Vulnerability Index, a broader analysis reveals significant differences among regions in France, Ireland, Germany, and Croatia.

Figure 3. Just Transition Fund territorial eligibility.



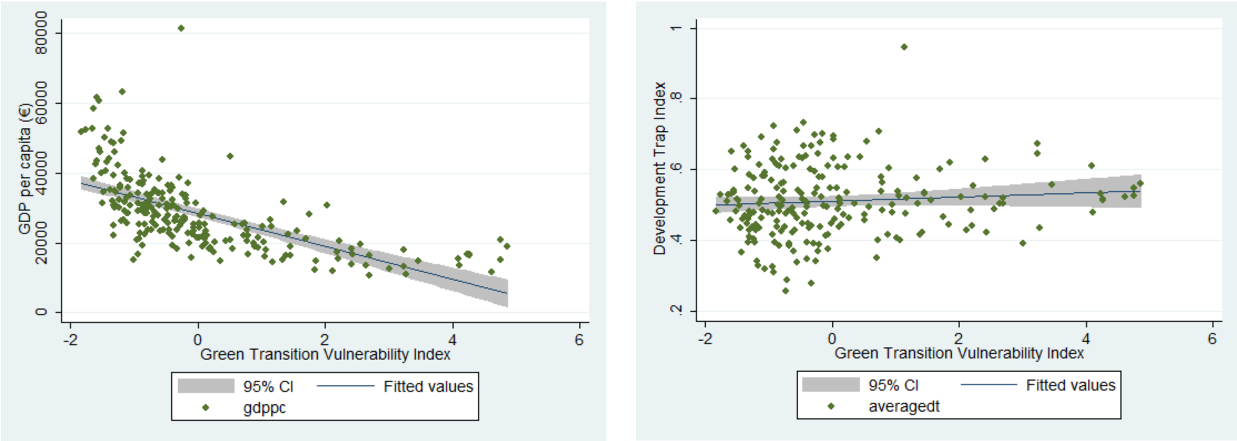
Source: European Commission, 2020b.

All in all, the mapping of the index and the resulting dichotomy between metropolitan regions and lagging-behind, often peripheral regions provides a good indication of where fiscal needs and investments for the retraining and reskilling of human capital will be greater. These investments will make or break the capacity of regions to transition towards green jobs and skills, while reshaping their productive and industrial systems.

To further investigate the relationship between lagging- and left-behind regions of Europe and their vulnerability to the green transition process, Figure 4 displays the correlation between the Green Transition Vulnerability index and regional GDP per capita, as a measure of relative economic backwardness, and Diemer et al.'s (2022) Development Trap index, as an indicator of economic stagnation.

Figure 4. Correlation between the Green Transition Vulnerability index and regional GDP per capita (i) and the Development Trap index (ii) (NUTS2 regions).

(i) (ii)



There is a strong negative correlation between the Green Transition Vulnerability index and regional GDP per capita (Figure 3). Poorer regions in the EU have higher scores in terms of their potential vulnerability to the green transition. They are thus more exposed to the negative impacts of the green transition. The negative relationship confirms the scenario presented in Figure 2 where the darkest shades of blue are concentrated in the Southern and Eastern peripheries of the EU; in regions that, at least in the case of the European Southern periphery, are already more vulnerable to climate change (van Daalen et al., 2022) and that, because of their relative low income, have received the highest level of support from the European Structural and Investment policy. The same findings hold when we restrict the sample to EU15 countries (see Appendix 3).

While poorer regions are more vulnerable to the regional impacts of the green transition, the same cannot be said for most regions that have suffered significant recent stagnation. The correlation between the Green Transition Vulnerability index and the Development Trap index is far weaker, although it becomes marginally more significant across EU15 countries (see Appendix 3). Some regions display high scores on both indices, such as Puglia, Sardinia, Thrace, or Centro in Portugal. But overall, there is no apparent correlation between the two indices. Notably, most Central and Eastern European regions —including the majority of regions in Poland, Romania, and Bulgaria— score high on the Green Transition Vulnerability index, but relatively low on the Development Trap one. While this can be due to a host of factors, a plausible hypothesis is that those regions have so far been able to escape long-term economic stagnation also thanks to their reliance on highly polluting sectors. These sectors are set to undergo profound transformations, raising questions about the capacity of those regions to maintain past economic dynamism and avoid falling into a development trap. Whereas more research is needed to shed light on the interplay between vulnerability to the green transition and development-trapped status, this first piece of evidence shows the importance of identifying vulnerable regions, which may subsequently fall into economic decline and stagnation due to a reconfiguration of the geography of jobs and industry.

Figure 5 presents the average scores in the Green Transition Vulnerability index by groups of regions defined in terms of GDP per capita (in PPS) relative to the EU mean. The graph shows that vulnerability to the green transition significantly decreases with income. It is greater at the lower end of the income distribution, especially in regions with 75 percent or less of the EU income average and affects much less those regions at the top of the income pyramid. Figure 6 illustrates the average vulnerability to the green transition by risk of economic stagnation, expressed as scores of the Development Trap index. Regions with low (<0.44) and medium-low (between 0.44 and 0.50) risk of economic stagnation and decline also display lower levels of vulnerability to the green transition. Regions with a medium-high (between 0.50 and 0.58) risk of economic stagnation and decline are much more vulnerable to the challenges posed by the green transition. This group of regions, comprising, for instance, Sardinia, the Centre region of Portugal, and Andalusia are bound to suffer more the double challenge of economic stagnation and vulnerability associated to the socio-economic transformations prompted by the green transition. Finally, regions with high risk (> 0.58) of falling into the regional development trap exhibit medium-high vulnerability to the green transition.

Figure 5. Average green transition vulnerability by levels of regional income.

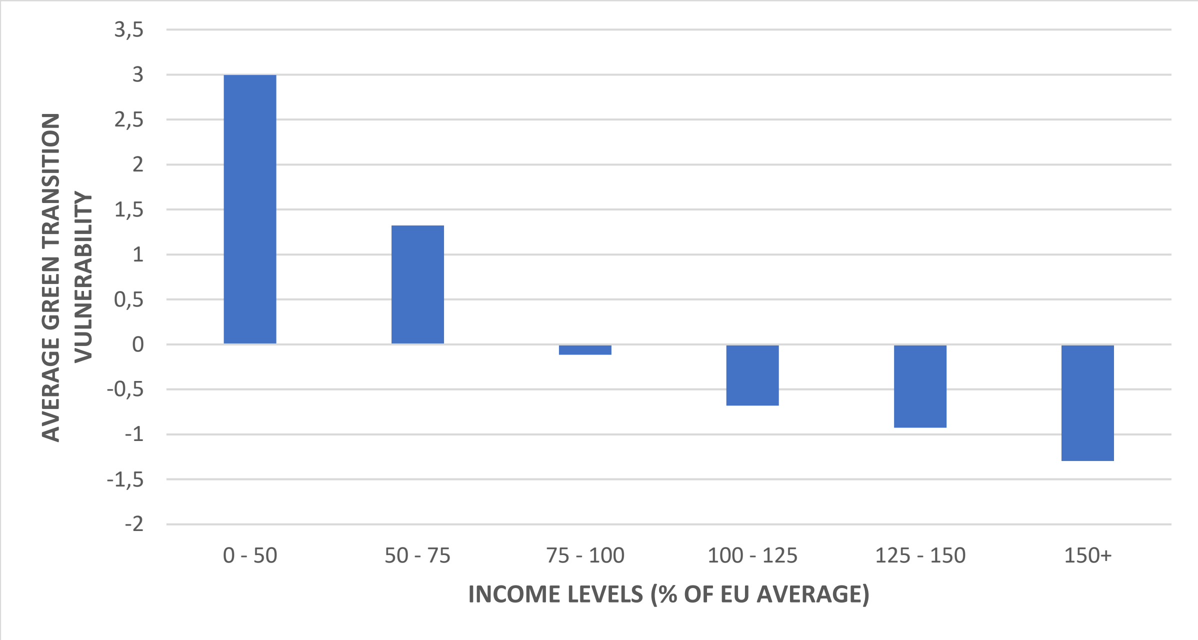


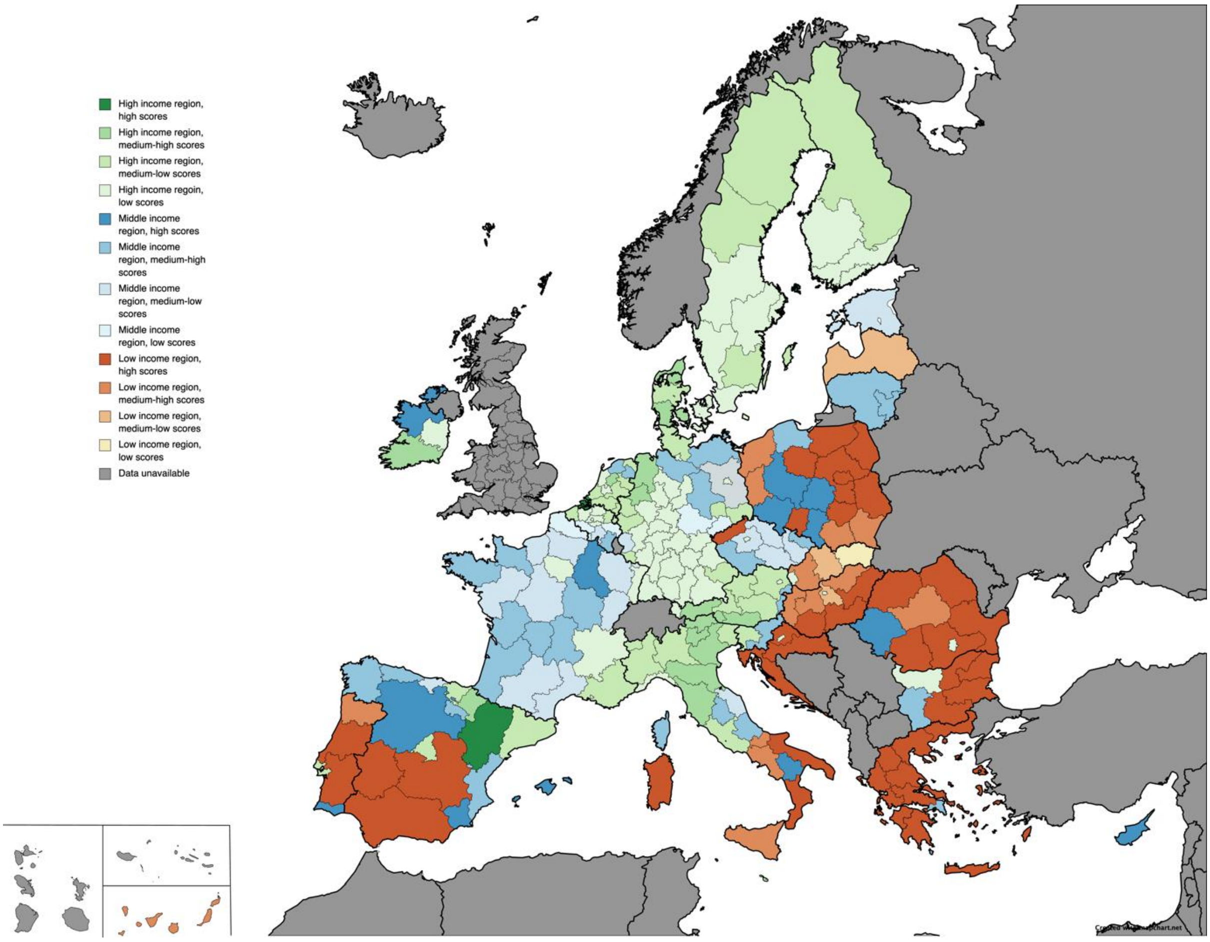
Figure 6. Average level of vulnerability to the green transition by levels of economic stagnation expressed as scores of the Development Trap index.

Notes: Quartiles of scores of the Development Trap Index (Diemer et al., 2022). A higher score on the Development Trap Index indicates a greater risk of economic stagnation.

Finally, although vulnerability to the impacts of the green transition is concentrated in the lower echelons of the regional income distribution, high scores on the Green Transition Vulnerability index can appear at various levels of GDP per capita. To showcase this, we use

Eurostat's classification of less developed regions, that is regions with a GDP per capita less than 75 percent of the EU average; transition regions, with a GDP per capita between 75 and 100 percent of the EU average; and more developed regions, with a GDP per capita higher than the EU average (Eurostat, 2021). Figure 7 illustrates the regional environmental vulnerability by income distribution. Some high-income regions, such as Aragon, and transition regions, such as Basilicata, Champagne-Ardenne, Algarve, will experience greater vulnerability to the implementation of the European Green Deal. This indicates that even dynamic semi-urban regions face considerable challenges in the transition to low-carbon societies. In contrast, metropolitan and capital regions rarely score high on the index, reinforcing the paradox outlined above: large agglomerations have been the territories where investment on climate policies has so far concentrated, while also remaining less vulnerable to the negative impacts of the green transition. In this context, the danger associated with leaving already left-behind places behind, namely already lagging-behind regions and rural areas, is substantial.

Figure 7. Regional Green Transition Vulnerability index by income group.



4. The rise of 'green' discontent and its policy implications

The green transition will reshape the geography of jobs and regional specialisation patterns. As our Green Transition Vulnerability index indicates, there is a serious risk that lagging-behind regions may be far more negatively affected. In these areas, it never rains but it pours, as the industrial and economic reconfiguration linked to the European Green Deal will pile on existing relative backwardness and territorial polarisation. Hence, the problem is no longer just environmental or economic in nature, but also social and political (Rodríguez-Pose, 2018). A green transition that piles on greater climate change vulnerability and deepens already existing spatial divides may make citizens in lagging-behind —and, to a lesser extent, in development trapped regions— reluctant to support the very environmental policies necessary for reducing greenhouse gas emissions and keep climate change at bay. The anti-green transition revolt may happen directly, as in the case of the French *gilets jaunes*, or through the increasing casting of votes for climate-change-sceptic parties. Against this backdrop, the emergence of green growth paths in the most vulnerable regions remains a fundamental need to ensure vulnerable regions can tap into the opportunities of the green transition.

The EU has taken great care in providing an EU-wide narrative to unite citizens in the need to combat climate change and drive up the support from the widest possible range of stakeholders. The potential asymmetric impacts of the green transition —especially during the transition period— risks jeopardizing this effort. A similar narrative targeted at those areas more vulnerable to the green transition needs to be developed. The existence of a 'just transition' fund is a major step in that direction. However, this fund mainly deals with the direct impact of the green transition and overlooks the potentially far more important indirect ones. Hence, if the European Green Deal is not to face frontal 'anti-green' discontent, a more proactive stance to identify the territorial risks and vulnerabilities of the implementation of the green deal needs to be put into operation.

General discontent across European regions has been on the rise. It has gripped the whole continent, but especially places that have struggled to benefit from the socio-economic gains of the digital transition and have suffered from negative externalities related to globalisation and processes of outsourcing and offshoring (Dijkstra et al., 2020). A growing ‘geography of discontent’ has emerged (McCann, 2019; Dijkstra et al., 2020). Many citizens —especially those living in more vulnerable areas— feel increasingly disenfranchised and disconnected with high-level governance and policymaking. Much of this discontent has been driven by policy initiatives aimed at leveraging efficiency and maximising economic returns by concentrating investment in core and prosperous regions (Dijkstra et al., 2020). As a result, people in left- and lagging-behind regions tend to have lower political trust than urban and peri-urban residents (Mitsch et al., 2021).

The growing territorial polarisation resulting from the interplay between inadequate endogenous endowments and exogenous global trends, such as the digital transition and globalisation, has started to backfire. Opposition to basic EU principles, such as free mobility of capital and labour, migration within EU borders, or economic integration and globalisation has been on the rise across the EU (Vasilopoulou & Talving, 2019). Many people in regions in economic decline have resorted to the ballot box —and in certain cases, revolts— to undermine the very factors on which recent economic growth and prosperity has been based (Horner et al., 2018; Rodríguez-Pose, 2018). This so-called 'revenge of the places that don’t matter' (Rodríguez-Pose, 2018) is rooted in years of relative decline, lack of opportunities, the relative deterioration of public goods and service provision, and perceived neglect. As the green transition is, as we have seen, bound to leave many left-behind places further behind, the European Green Deal may end up as an additional territorial grievance. The rise of populism and support to anti-establishment right-wing parties —parties which often champion anti-green policies— will thus slow down the implementation of the European Green Deal, if not derail it altogether.

There is already evidence that the adoption of measures to save the planet is generating a backlash —a sort of ‘green’ discontent— in vulnerable regions (Broekel & Alfken, 2015; Arndt et al., 2022). The revolt of the *gilets jaunes* (yellow vests) has, in part, been triggered by the drive by the French state to combat climate change (Martin & Islar, 2021). At the end of 2018, the introduction of a tax on diesel fuel triggered a nation-wide grassroot protest which saw first thousands of workers blocking roads and roundabouts in small and mid-size towns. The protest later expanded to encompass larger urban areas, with regular weekly riots in some of the wealthiest neighbourhoods in Paris. Motorists revolted against the 2018 increase of the carbon component of the domestic consumption tax on energy products and against an additional diesel tax aimed at equating the price of diesel to that of gasoline by 2022 (Mehleb et al., 2021). At times, protests resulted in violent confrontation with police, with several deaths occurring (Chamorel, 2019). Whereas the French carbon tax represented the trigger of the insurrection, it is far from being the sole determinant of the political cleavages which took centre stage in France. Past research has highlighted the relationship between pre-existing underlying socio-economic constraints and the demands of the yellow vests movement (Martin & Islar, 2021; Bourdin and Torre, 2022). For instance, the planned decline of public services in falling-behind regions, such as the reduction in the number of schools, hospitals, and post offices and the abandonment of regional railway lines in favour high-speed rail connecting metropolitan regions has been regarded as a trigger of the conflictual social climate that has engulfed many French vulnerable regions (Bourdin & Torre, 2021).

Far from being an isolated case, the yellow vests movement has been followed by other episodes of social unrest throughout Europe. At the end of 2019, farmers in the Netherlands took to the streets to protest against new environmental policies aimed at the reduction of nitrogen emissions (Van der Ploeg, 2020). According to the Dutch government's plans, more than 11,000 farms will have to close, while almost 18,000 farms will have to significantly reduce their livestock in order to reach the policy targets (Holligan, 2022). The Farmer-Citizen Movement, a political party created in 2019 in the aftermath of the protests and whose aim is to reverse the nitrogen policy, is catalysing discontent among farmers. It has been surging in the polls (Holligan, 2022) and in March 2023 came first in the Dutch Provincial Elections. Farmers protests highlight the risk that the bill for the necessary ecological transition will be footed by the poor, which in the case of the agricultural sector are often family-owned, small-scale farms that face a whole new set of environmental restrictions (Van der Ploeg, 2020; Leitheiser et al., 2022).

Opposition can also emerge from those who had previously supported climate action and mitigation policies. Extensive evidence on the 'Not In My Backyard' (NIMBY) movement unveils the degree of antagonism that emerges when green transition policies are implemented and costs are concentrated in specific areas (O'Grady, 2020; Mehleb et al., 2021). In the German *Land* of Baden-Württemberg, the blueprint of policies to locate wind turbines and solar farms radically changed the electoral preferences among residents who had previously voted for the Green Party (Mitsch & McNeil, 2022). This highlights the dilemma of having people supporting climate mitigation policies as a global collective action issue, while often resorting to 'not in my backyard' stances towards the implementation of those same climate policies (O'Grady, 2020).

Beyond the German case, the installation of wind and solar farms regularly withstands significant local resistance. Similar conflicts have emerged across Polish and Danish regions for the deployment of wind farms, with local communities opposing the construction of renewable energy installations from which they perceive little or no benefit (Clausen & Rudolph, 2020; Nowak et al., 2023). In the region of Coastal Norway, opposition to new installations of wind farms and transmission lines led to significant delays with a first local referendum held in 2002 regarding the construction of the Frøya wind farm, a concession granted in 2012 and construction terminated in 2019 (Sovacool et al., 2022). Research has also identified the emergence of a functional dichotomy between the preservation of land with strong agricultural potential and the massive expansion of renewable energy production across rural areas (Poggi et al., 2018). Moreover, the issue of natural landscape alteration has affected the social acceptance of both offshore and onshore wind farms, and only recently there have been attempts to develop quantitative indicators of the visual impact of new wind farms that can be inserted in cost-benefit analyses (González-Rodríguez et al., 2022).

The geography of discontent across EU regions is also already visible and manifest in variations in citizens' attitudes towards the attainment of the sustainable development goals (SDGs) via EU policy initiatives. Past research has found a strong correlation between levels of overall economic development and support for environmental policies, signalling that places which will be most negatively affected by the outflow of capital and skilled labour may quickly turn their back on sustainable development targets (Pirvu et al., 2019). This may accentuate recent trends in greenhouse gas emissions across EU regions: whereas some generally less vulnerable regions have significantly reduced their carbon footprint, many of the more vulnerable ones —as identified in the Green Transition Vulnerability index— have experienced steep increases in their per capita fossil fuels emissions (JRC, 2019).

The emergence of the yellow vest movement, the farmers' revolt across Europe in 2019, the increasing casting of votes for climate-sceptic parties, and local resistance to renewable energy installations point to the many dangers faced by the green transition in an already territorially polarized economic and political context. Not all is doom, however. More proactive policy initiatives can, at least in theory, mitigate the negative impacts of the green transition in vulnerable regions, while potentially addressing movements of local resistance. Research has shown how path development towards green industries can happen in vulnerable regions without green specialisation through both path emergence —that is, by importing existing technologies to the local context— and path upgrading —that is the attraction of higher-value added activities to the region vis-à-vis low skill manufacturing in green industries (Grillitsch & Hansen, 2019). The case of Schleswig-Holstein, a development-trapped region in northern Germany, is representative as of how an underperforming region can become a leader in renewable energy production by embedding renewable energy policies in smart specialisation strategies. Schleswig-Holstein, with a total of 18,400 people employed directly or indirectly in the renewable energy industry, is now at the forefront of the German effort in terms of the switch towards renewable energy, as well as in local political engagement in renewable energy sectors (Ulreich & Kirrmann 2017; Steen et al., 2019). In a broader sense, the implementation of transition approaches, as outlined in the 2020 EU Industrial Strategy for the single market, aims to transform polluting industrial ecosystems. This transformation can lay the groundwork for the development of new pathways in rural and lagging regions (European Commission, 2022a).

Such opportunities for green specialisation in vulnerable regions, however, come with a few caveats. First, as seen in the case of wind turbines in Germany and Poland, there is the issue of social acceptance by local communities. In this sense, community-owned renewable energy installations have proven to be generally more palatable to local populations, as shown in the case of the current policy regime in Scotland and Murau in Austria and may provide a suitable and more acceptable alternative than third-party deployments of renewable energy (Grillitsch & Hansen, 2019; Clausen & Rudolph, 2020). Second, vulnerable regions need policies that provide directionality, i.e., the goal of green industry development, in order to set a shared vision and strategy to tap into the opportunities of the green transition. Whereas this is generally a well-understood idea among researchers and policymakers alike, policy mixes that provide directionality are complex, and they include facilitating policy experimentation, nurturing new green markets, stimulating resource reconfiguration, and coordinating various stakeholders (Jakobsen et al., 2022). The extent to which vulnerable regions with limited institutional capacity can develop such policies is debatable. Transformative policy mixes that provide directionality towards green specialisation are especially hard to support in regions that specialise in traditionally non-green industries due to existing policy regimes that make local actors more risk-averse towards a radical transition (Howlett, 2014).

The risk of increasing discontent in places already lagging behind cannot be taken lightly, and new policy initiatives aim to prevent further regional polarization linked to the implementation of climate policies. 'Just transition' intervention will go a long way in addressing the needs of the residents of regions where coal-fired power plants or coalmines are being closed (del Guayo & Cuesta, 2022). Research stemming from the Ruhr (Germany) and Victoria (Australia) highlights the potential of just transition policies to alleviate the negative impacts of climate policies (Harrahill & Douglas, 2019; Galgóczi, 2019). That said, the idea of a just transition has remained mostly confined to coal-dependent and mining regions, both at the EU and national levels. The EU Platform on Coal Regions in Transition, for example, supports a limited group of 42 EU regions in twelve member-states, where the transition to low-carbon economies is likely to translate in job losses in the coal industry (European Commission, 2020a). Similarly, Spain's Strategy of Just Transition requires agreements between governments, unions, and business in all regions affected by climate policies, such as the closing of mining pits (IndustryALL, 2018). Yet, the green transition has many other potential and often indirect negative externalities that can affect already vulnerable regions, including the construction of renewable facilities in rural areas, environmental impacts, energy poverty, and so on. Winners and losers go well beyond coal regions and workers (del Guayo & Cuesta, 2022).

Against this backdrop, the idea of a just transition merely focused on the repercussions related to the more direct regional impacts of climate policies is unlikely to quell 'green discontent' in left-behind places. Extreme right-wing parties have spotted an opportunity and are already capitalizing on this discontent by openly promoting anti-green transition policies. Marie Le Pen, of the extreme right-wing *Rassemblement National*, run for president on a platform proposing a moratorium on wind energy and the establishment of new wind turbines. Giorgia Meloni, of the right-wing *Fratelli d'Italia*, emerged victorious in the Italian September 2022 legislative elections by promising to diversify energy sources, building regasification plants, promoting fracking, and investing in nuclear energy.

There is, therefore, a need to adopt a more holistic approach to the differential regional impacts of the green transition and to design and implement more proactive and well-resourced —both in financial and human terms— policies to tackle the drivers of green-transition-related vulnerabilities. The case of the EU Just Transition Fund is emblematic. Whereas the Fund's mission is ambitious, aiming to support regions in a number of activities, including investments in SMEs to diversify and restructure, investments in green energy and energy efficiency, and in the circular economy, its budget at the time of writing of 17.5 billion euros is, however, well below both the Commission's and Parliament's proposal and has been deemed inadequate to cover its scope of action (del Guayo & Cuesta, 2022). Other holistic and more high-reaching interventions will be needed to tackle the territorially differentiated negative ramifications of the green transition.

Conclusions

Achieving the green transition in the EU has become an urgent matter. Much research has gone into assessing the differentiated impacts that climate change and extreme meteorological episodes can have across territories (e.g., van Daalen et al., 2022). Similarly, no resources have been spared into how to reach a zero emissions society, the end goal of the green transition. But much less attention has been put into the potential bumps on the road to reach this goal. Our study has aimed to cover the gap in existing knowledge, by delving into the regionally diverse impact of the green transition in the EU, focusing on the potential regional impacts of the policies implemented to address climate change. We provide an analytical framework to identify and assess the regional impacts of the green transition, placing emphasis on both its direct —associated to carbon emissions from fossil fuels and reliance on brown energy— and indirect impacts —the resulting shocks and transformations linked to productive, regulatory, and behavioural shifts.

We have shown that green transition road can, indeed, be bumpy. The territorial impact of the green transition is bound to be uneven from a geographical perspective. Some regions are more exposed than others to the major shifts prompted by the European Green Deal. In many of these more vulnerable regions, the green transition vulnerability falls on top of other, pre-existing cleavages that are at the root of social and political discontent. Many economically left-behind regions could be further left behind by both the effects of climate change and of the measures to combat it. Regions with a high level of carbon emissions from fossil fuels and high reliance on transitioning sectors, such as road transportation, heavy industry, tourism, and agriculture, are far more vulnerable to the green transition. Many of these are already lagging-behind regions in the Southern and Eastern peripheries of Europe. Moreover, vulnerability to the negative externalities of the green transition is correlated to GDP levels, with poorer regions being more exposed. All in all, metropolitan regions and capital cities are better equipped to face the changes in regulatory and behavioural patterns elicited by the transition to low-carbon economies, while lagging-behind regions —to a greater extent than falling-behind ones— are far more exposed.

The interplay between the weaknesses of lagging-behind regions and the game changing implications brought about by the green transition may lead to a series of mutually- and self-reinforcing negative effects, which can result in an increase of regional polarization across EU regions. The risk that the implementation of the European Green Deal will reinforce the path dependency of vulnerable regions calls for across-the-board policy actions. These actions need to be designed to limit the negative externalities which may follow the transition to lower-carbon economies and societies. They also require more participatory, transparent, and equitable approaches to the introduction of policies with asymmetric impacts across a country's regions (Doukas et al., 2020). More consultation with local communities on matters related to energy transition policy will not only help win public support for the green transition but will also make sure than the transition takes into account the economic and social needs of more vulnerable regions, mitigating negative externalities and galvanising local potential (Carattini et al., 2019; Mehleb et al., 2021).

Finally, a new form of discontent —a 'green discontent'— may imperil attempts to further decarbonize economies, especially in less prosperous, highly emitting territories. Social discontent in territories that will bear the brunt of the green transition may erupt in social protests, as seen with the 'yellow vests' revolt in France, and erode public support for climate action. A real and/or perceived large imbalance in the distribution of benefits and costs associated with the process can shift attitudes and potentially undermine the ambitious goals set by the European Commission and national governments in achieving carbon neutrality. Moreover, it could also contribute to the election of governments that oppose or, more likely, hinder the green transition, a trend that is becoming increasingly common in recent times. To avoid derailing the green transition entirely, it is crucial to smooth out the bumps on the road and address the obstacles along the way. This requires implementing more ambitious policy initiatives aimed at supporting and developing —and not simply compensating— highly vulnerable regions in their transition to green economies. Moreover, it is essential to shift focus towards how the implementation of the green transition can serve as a catalyst for greater prosperity and economic dynamism in all regions, developing better targeted and more realistic interventions and taking into consideration the specificities of every place. By doing so, we can avoid the potential pitfalls of the transitional process and effectively tackle one of the greatest challenges of our time.

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Appendix

Appendix 1 — The Green Transition Vulnerability index: Methodological considerations and descriptive statistics

Principal Component Analysis (PCA) has been widely used in the construction of composite indices across the social sciences (Abdi & Williams, 2010). The wide application of PCA derives from its ability to reduce the number of variables in a data set into a smaller number of 'dimensions'. PCA creates uncorrelated indices where each component is a linear weighted combination of the initial variables. In the case of a set of given variables from X_1 to X_n, the derived principal components can be expressed as:

$$PC_1 = a_{11}X_1 + a_{12}X_2 + \ \dots + a_{1n}X_n$$
$$PC_m = a_{m1}X_1 + a_{m2}X_2 + \ \dots + a_{mn}X_n$$

where a_{mn} represents the weight for the mth principal component and the nth variable.

The first step in the construction of an index through PCA is the identification of variables. In our case, a first selection of variables was undertaken based on existing theoretical and empirical research pointing at the influence certain variables may have in terms of a region's vulnerability to the green transition. This constituted a 'wish list' of indicators to be included in our index. A second step consisted in assessing data availability. Out of our desirable variables, those indicators that were available on publicly accessible databases were included in the index.

The accuracy and validity of PCA-based indices increases when variables are correlated, but also when the distribution of variables varies across cases, or in our case, regions. Generally, the variables with the greatest variance across regions are given more weight in the PCA (McKenzie, 2003). For instance, a variable with zero standard deviation is given zero weight in the PCA. With this in mind, we produce the descriptive statistics for all variables, reporting their means, frequencies, and standard deviations.

Descriptive Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
CO_2 emissions from fossil fuels per head	238	8.179	7.296	.137	76.458
Change in CO_2 emissions, 1990-2018	237	-7.633	35.005	-75.526	175.273
Transition regions (0/1)	246	.114	.318	0	1
Economic account in agriculture, by GDP	237	.05	.048	0	.216
Share of employment in agriculture	238	.025	.029	0	.23
Population of bovines per head	238	.211	.278	0	2.159
Arrivals of tourists by GDP	235	108.578	137.832	13.921	1414.301
Number of tourist establishments by GDP	235	.105	.49	0	7.048
Cooling degree days	231	103.822	142.823	0	802.53
Value of the mining and quarrying sector by GDP	238	.001	.003	0	.034
Road freight transport (loading) by GDP	239	1.481	2.779	0	38.255

The table above unveils a great deal of variation across variables and regions. For instance, the Greek region of West Macedonia exhibits over 76 tCO_2 emissions from fossil fuels per head, while Mayotte accounts for less than 0.5 tCO_2 emissions from fossil fuels per head. Most variables show high variation across regions, with only the population of bovines being relatively equally distributed across most regions, except for capital cities. Consequently, the bovine population is given a relatively low weight in the PCA.

Finally, we construct the index based on the lowest frequencies available per variable. In our case, a total of 231 observations were included. We therefore refrain from replacing missing values with the mean value for that variable, as proposed by other studies employing PCA (e.g., Gwatkin et al. 2000). This significantly reduces the potential risk of 'clumping', which can happen when there are variables with small ranges, due to the allocation of mean values to missing observations (McKenzie, 2003).

Appendix 2 — Principal Component Analysis for the calculation of the Regional Environmental Risk Index

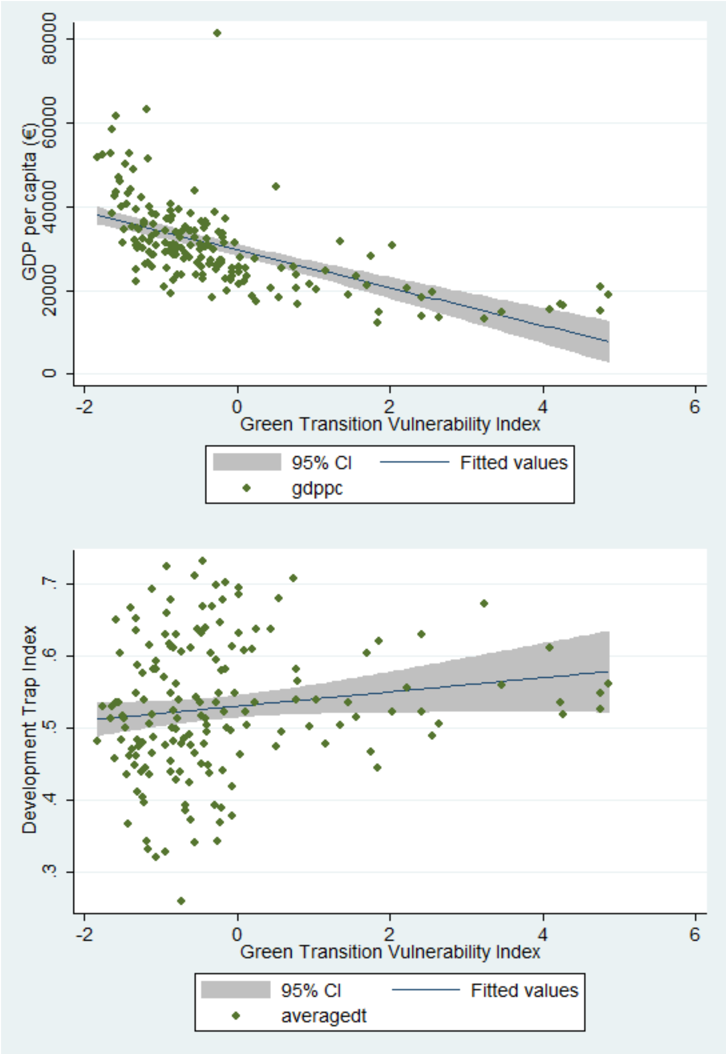
The Eigenanalysis of the Correlation Matrix shows that the first principal component (PC) accounts for around 19% of the total variation and it has an Eigenvalue larger than 2. The second PC accounts for another 17% of the variance and it has an Eigenvalue still larger than 1. The first two PCs explain together around 36% of the total variability.

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.122	0.249	0.193	0.193
Comp2	1.872	0.426	0.170	0.363
Comp3	1.446	0.269	0.131	0.495
Comp4	1.176	0.219	0.107	0.601
Comp5	0.958	0.051	0.087	0.689
Comp6	0.907	0.151	0.082	0.771
Comp7	0.755	0.189	0.069	0.840
Comp8	0.566	0.030	0.051	0.891
Comp9	0.536	0.111	0.049	0.940
Comp10	0.425	0.187	0.039	0.978
Comp11	0.238	.	0.022	1.000

We choose the first principal component (PC) to construct the Regional Green Transition Vulnerability index as our composite measure of a region's vulnerability to the green transition. The coefficients of the first component emphasize primary sector variables, such as gross value added and employment agriculture, assigning each a large weight of 0.531 and 0.549 respectively in the index. Other factors, such as a reliance on tourism, tourist arrivals relative to GDP, and cooling degree days —which reflects the energy needs of each region— also feature significantly in the first principal component.

Variable	**Comp1**	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7
CO_2 emissions from fossil fuels per head	**0.150**	0.361	0.147	0.507	-0.011	0.024	-0.560
Change in CO_2 emissions, 1990-2018	**0.102**	-0.173	-0.281	0.526	0.559	0.209	0.289
Transition regions (0/1)	**0.147**	0.423	0.414	0.013	0.143	0.230	-0.175
Gross value-added in agriculture, as a share of GDP	**0.531**	0.111	-0.343	-0.200	-0.027	-0.019	-0.183
Share of employment in agriculture	**0.549**	0.103	-0.177	-0.332	-0.048	-0.130	0.066
Bovine cattle by land area	**0.032**	0.115	-0.545	0.168	-0.334	0.564	-0.022
Arrivals of tourists relative to GDP	**0.340**	-0.399	0.266	0.158	-0.191	0.095	0.023
Number of tourist establishments relative to GDP	**0.211**	-0.333	0.317	0.205	-0.508	0.217	0.134
Cooling degree days	**0.346**	-0.391	0.118	-0.043	0.449	-0.015	-0.232
Value of the mining and quarrying sector relative to GDP	**0.190**	0.382	0.304	-0.135	0.156	0.347	0.577
Road freight transport (loading) relative to GDP	**0.213**	0.236	-0.064	0.447	-0.181	-0.625	0.359

Appendix 3 — Correlation between the Green Transition Vulnerability index and regional GDP per capita (i) and the Development Trap index (ii) (NUTS2 regions for EU15 countries).



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