



DEMS WORKING PAPER SERIES

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No. 568 – February 2026

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Left behind places and regional resilience to COVID-19 shock in Europe

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Abstract

Current turbulent times pose challenges not only for countries, but also – and above all – for regions within them. However, economic resilience of left behind places is still underexplored, especially in the light of entrenched regional disparities. The aim of this paper is to investigate the nexus between regional development and economic resilience across 898 European NUTS 3 regions during the COVID-19 pandemic. To go beyond the GDP-based approach, we construct a multidimensional “left behindness” index. Our findings show that left-behind places, as identified through this multidimensional approach, were relatively more successful in resisting the immediate pandemic shock, while more developed regions demonstrated a stronger recovery capacity. The analysis also highlights that international trade, industrial specialization and the share of public employment acted as determinants of these divergent resilience trajectories. The results suggest that policymakers should adopt a differentiated strategy by strengthening the resistance of more advanced regions and enhancing the recovery capacity of left behind places to reduce persistent regional disparities.

Keywords: regional resilience; territorial disparities; left behind places; multidimensional left behindness index; resistance; recovery

JEL codes: R11; E32

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1. Introduction

Two game-changing concepts have recently emerged in the regional economics literature: resilience and left-behindness. **Resilience** is defined as the ability of regional economic systems to withstand disruptive shocks through resistance, rebound and adaptation to post-hoc trajectories (Pendall et al. 2010; Pike et al. 2010; Simmie and Martin, 2010; Martin, 2012; Martin and Sunley, 2015; Faggian et al. 2018). It has been growing fast in popularity in recent years, especially in response to the pandemic shock. **“Left behindness”** (LB), as a way to summarise persistent regional disparities, has also become a very widespread concept in both the academic and policy arenas. It often refers to economically and socially struggling territories due to forces such as globalisation, tertiarisation and city-oriented discourses, leading to political discontent (Rodríguez-Pose, 2018; Rodríguez-Pose et al., 2021; Rodríguez-Pose et al., 2024; MacKinnon et al., 2024; Le Petit-Guerin et al. 2025). These places are characterized by peripheralisation (Le Petit-Guerin et al., 2025), poverty (Davenport and Zaranko, 2020), remoteness, lower income and slower growth rate (Fiorentino et al., 2024), lower skills and lower quality of infrastructure (Pike et al., 2024), outmigration and disconnection from knowledge networks (MacKinnon et al., 2022), ageing and population decline (McCann, 2017).

Despite a growing interest in understanding regional disparities, the empirical evidence on the relationship between economic resilience and regional left-behindness is still limited. Investigating this relationship is important to uncover possible “pockets” of resilience even in left behind regions. In fact, the lagging regions may have certain advantages in resisting exogenous shocks - e.g. they might be less affected by the business cycle, reducing therefore their exposure to the global shocks (Rodríguez-Pose and Fratesi, 2007; Fratesi and Rodríguez-Pose, 2016) - although they might then struggle to recover because of lower productivity, lack of human capital and technical advancements, inadequate infrastructures and lack of all the positive externalities connected to agglomeration (Krugman 1991; Ciccone, 2002; Capello et al. 2015; Eraydin, 2016; Giannakis and Bruggeman, 2017a; Giannakis and Bruggeman, 2017b). Understanding how economic resilience varies across different types of regions is essential for designing effective policies to reduce regional disparities and foster local economic development.

The aim of this paper is therefore to investigate the relationship between left-behindness and resilience of European NUTS 3 regions, with a focus on the economic downturn induced by the COVID-19 pandemic. For this purpose, we construct a multidimensional index of regional LB to

identify the better- and worse-performing regions in the European Union (EU). Moreover, we not only look at overall regional resilience, but also at the two separate stages of it, i.e. the initial resistance and the subsequent recovery, and analyse their determinants during the COVID-19 shock.

Our contribution to the literature is twofold. First, we propose a new multidimensional LB index, which is a more comprehensive and nuanced measure on a continuous scale. Moreover, we focus on the European NUTS 3 regions providing a more geographically disaggregated analysis of regional disparities from a multidimensional perspective. Second, focusing on the pandemic as a shock, we give new insights on the relationship between multidimensional LB and the different stages of regional resilience.

Our results show that the patterns of resistance and recovery vary with the degree of left-behindness and, as expected, left behind places are more resistant than central locations, i.e. better off in the initial stage of a shock, but slower in recovery. In other words, while it has been said that the pandemic was a V-shaped shock, the exact shape of the V depended on centrality.

The remainder of paper is structured as follows. Section 2 outlines existing approaches to measure regional LB from a multidimensional perspective and review the concept of regional resilience. Section 3 contains data and methodology applied in our analysis. The results are described in Section 4, while the last section concludes.

2. Literature review

Two interrelated strands of literature are relevant for our study: (i) the contributions on how to measure regional “*left behindness*”, (ii) the literature on the concept of *regional economic resilience*.

2.1 Measuring regional left behindness

Recent studies have conceptualized “left-behindness” (LB) as a multidimensional phenomenon shaped by economic, social, demographic, political, and cultural factors (MacKinnon et al., 2022). Comim et al. (2024) systematically reviewed the literature, categorizing the contributions into four main approaches: ‘econcore’, ‘econwider’, ‘left-behind places’, and ‘geodiscontent’. These approaches vary in scope and comprehensiveness, ranging from narrower definitions, focused on ‘pure economic development’, to broader perspectives that emphasize fairness, equity and the social processes underlying regional disparities. These approaches vary in scope and comprehensiveness, ranging from narrower definitions, focused on ‘pure economic development’, to broader perspectives that emphasize fairness, equity, and the social processes underlying regional disparities. Left behind

regions typically experience deficits across multiple dimensions, including lower employment rates and productivity, interregional pay disparities, higher material deprivation and poverty rates, inadequate infrastructure, underinvestment, substandard housing, and limited social mobility (Carneiro et al. 2020; Davenport and Zaranko 2020; Hendrickson et al., 2018). These challenges contribute to left behind places being characterized by lower living standards, lower levels of education and skills, poorer health outcomes, political discontent and resentment, and higher interpersonal inequality (Rodríguez-Pose, 2018).

A common issue in all the empirical studies is managing the discrepancies among different indicators, which raises the question of how to rank regions. To illustrate this Comim et al. (2024, p. 167) ask the question “*How could we compare one region with better GDP per capita with another with better health care?*”. Rankings are only possible when composite indices are created, often based on arithmetic or geometric means that collapse and conceal potential incompatibilities across different dimensions into a single aggregated measure (Comim et al. 2024).

An overview of the composite indices of regional LB recently proposed is shown in Table 1. As it can be seen the multidimensional approach to understanding regional LB relies on several indicators representing the regional performance in the selected domains. The most common is the economic domain, which is often represented by the GDP per capita. Other domains considered in recent studies include social, demographic, and – less frequently – infrastructural ones, allowing therefore to move beyond the GDP indicator and capture additional facets of regional underperformance.

- Insert Table 1 about here -

Davenport and Zaranko (2020), construct a Left Behind index for the UK using the weighted arithmetic average of four standardized outcome measures: employment rate, employee weekly pay, formal education and health. Specifically, the index is computed using the inverse of the covariance matrix, ensuring that it captures the common variation among outcomes while accounting for their correlations. Indicators that are highly correlated receive lower weights, whereas those providing more distinct information are assigned greater weights. This method, developed by Anderson (2008) assumes that indicators contribute additively to the overall index, allowing improvements in one indicator to compensate for a decrease in another one. As a result, the underlying indicators are treated as substitutes rather than complements.

A similar composite index based on an arithmetic mean is used in Connor et al. (2024) to rank Incorporated and Census Designated Places (CDPs) in the US, which roughly correspond to

municipalities in the European territorial classification. For each time period analysed, the authors determine the percentile rank of each region for four indicators, namely poverty rate, median household income, unemployment rate and college attainment. The left behind index is then the arithmetic average of these percentile ranks.

Beyond composite indices, two other approaches identify left behind regions without necessarily establishing a complete ranking: a threshold-based method and cluster analysis. Faggian et al. (2024) propose a threshold-based method using indicators in both the economic (the GDP criterion according to the EU Cohesion Policy, the unemployment rate, and the GVA growth rate) and social (poverty rate and income inequality) domains. For the second approach, Jessen (2024) and Houlden et al. (2024) adopt cluster analysis, combining multiple dimensions of deprivation and their evolution over time, to classify left behind regions according to distinct development paths.

As for the territorial unit of analysis, existing studies for the European countries commonly focus on NUTS 2 level, while lower levels of territorial disaggregation (e.g., provinces or municipalities) are less frequent. Among the few exceptions are the studies by Connor et al. (2024), Davenport and Zaranko (2020), Houlden et al. (2024), and Jessen (2024), which rely on more granular spatial data. However, in all these cases the analysis is restricted to a single country.

In our study, although following an approach similar to Davenport and Zaranko (2020), we propose a multidimensional definition of regional resilience for the whole of Europe and not just a single country. This allows a cross-country comparison – at NUTS 3 level – which is currently missing. Moreover, our definition of LB is more comprehensive as it includes ten socio-economic indicators, aggregated using a geometric mean. This aggregation method is preferred to the linear method, because the latter relies on two strong assumptions: interdependence among outcomes and full compensability, meaning that a higher value in one indicator can fully offset a lower value in another. In contrast, the geometric mean allows only partial compensability, preventing full compensation between indicators (Liberati et al., 2021).

2.2 The concept of regional resilience

The definition of resilience, originally developed by other disciplines, has been recently introduced in social sciences, attracting growing academic attention. This is particularly true in the field of regional economics and economic geography (Martin, 2012; Martin and Sunley, 2015; Faggian et al. 2018).

There are three main conceptualizations of regional resilience: engineering resilience, ecological resilience, and evolutionary resilience. Engineering resilience, the first and maybe simpler

one, refers to the ability of a region to “*bounce back*” or, in other words, return to its pre-shock equilibrium state, following a disturbance (Martin, 2012; Martin and Sunley, 2015). Ecological resilience is slightly different and is defined as the extent of a region’s capacity to “*absorb*” a shock, while still remaining in its current equilibrium state (Martin, 2012; Martin and Sunley, 2015). Both engineering and ecological resilience assume the existence of a pre-shock equilibrium state, which is either maintained or recovered by the system after the shock. The third type of resilience, the evolutionary or adaptive one, refers to region’s ability to “*bounce forward*”. This third type of resilience involves a region’s adaptability, adjustment, reorganization and reconfiguration of its structure, which might result in a new and possibly improved development path (Faggian et al. 2018; Modica and Reggiani, 2015).

Different stages of resilience have been identified by Martin (2012) and Martin and Sunley (2015), namely (i) resistance to the initial shock or disturbance (ii) post-shock recovery speed, and (iii) re-orientation and renewal, meant as the region’s ability to undergo a structural change as the result of the shock and adjust its growth path.

Besides choosing the definition of resilience and its dimensions, empirical studies also need to specify the nature of shocks experienced (resilience “*to what*”) as well as indicators of regional resilience (resilience “*of what*”) (Faggian et al., 2018). Regarding the former, empirical papers have often found an uneven geography of resilience across regions in response to economic crises and recessions (Compagnucci et al., 2022; Urso et al., 2019; Giannakis and Bruggeman, 2017; Fingleton et al., 2012). Such asymmetries have been identified both from a national and European-wide perspective, reporting the presence of less resilient regions. Other studies have investigated regional resilience to natural disasters (Fantechi and Modica, 2023; Bănică et al., 2020; Fantechi et al., 2020; Jara and Faggian, 2018). Moreover, other types of shocks studied in the literature include institutional, organizational, man-made, technological and epidemic ones (Sutton and Arku, 2022), with the last experiencing increasing attentions recently (Sutton et al., 2023).

Regional resilience is a complex and multidimensional phenomenon, which can be conceptualized and operationalized from either a uni- or multi-dimensional perspectives. A variety of indicators have been used in the literature to measure it, most commonly employment (Faggian et al., 2018; Di Caro, 2017; Giannakis and Bruggeman, 2017; Han and Goetz, 2015; Fingleton et al., 2012) and the GDP per capita (Sensier et al., 2016; Cellini and Torrisi, 2014). From a policy perspective, the European Commission’s resilience dashboard¹ also provides synthetic indices of regional resilience, interpreted in terms of capabilities and vulnerabilities, rather than outcomes.

¹ More information on the resilience dashboards is available at: https://commission.europa.eu/strategy-and-policy/strategic-foresight/2020-strategic-foresight-report/resilience-dashboards_en

Given the complexity surrounding the concept of resilience, our choice was to use a more comprehensive multi-dimensional approach, but restricted to the first two phases of the approach by Martin (2012) and Martin and Sunley (2015), i.e. *resistance* and *recovery*. We do not address in this work *re-orientation* and long-term renewal, since it involves structural transformations and growth trajectories beyond the scope and timeframe of our analysis.

3. Data and Methodology

The study covers 898 NUTS 3 regions across 13 EU countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain and Sweden. The analysis focuses on the period 2019-2022, which encompasses the economic turbulence triggered by the COVID-19 pandemic. The pandemic originated in China and rapidly spread across the globe, becoming one of the most disruptive shocks to modern economies.

To illustrate the economic downturn of this period, Figure 1 displays the evolution of real GDP aggregated for the Euro area (19 countries) for the period 2015-2023 (Eurostat, 2024). It is clear that the aggregate economy reaches a peak in 2019 before contracting sharply – by about 6 % - when pandemic-related restrictions were in place. A rapid rebound followed in 2021, with GDP nearly returning to its pre-shock level, and continued recovery is observed in 2022 and 2023. This V-shaped trajectory underscores both the depth of the initial shock and the speed of the subsequent recovery, highlighting the relevance of investigating territorial resilience patterns in this context.

- Insert Figure 1 about here -

The variables and data used in this paper are summarized in Table 2. Our analysis relies on three sets of variables: (i) resilience variables, (ii) Left Behindness variables, and (iii) control variables. Following the established literature on regional resilience, we construct five indicators based on dynamics of real GDP in NUTS 3 EU regions. First, *Resistance* is defined as the percentage change (logarithmic ratio) in real GDP between the pre-pandemic peak in 2019 and the trough in 2020, which reflects the depth of the initial recession induced by the COVID-19 shock. We retrieve the data on the real GDP from ARDECO (2025) and Eurostat (2025) databases.

- Insert Table 2 about here -

Second, *Recovery* measures the post-shock rebound following the 2020 trough in 2021.

Specifically, *recovery21* measures one-year recovery and is defined as the percentage change in real GDP between 2020 and 2021, while *recovery22* stands for two-year recovery, i.e., the percentage change in real GDP between 2020 and 2022. Finally, *Total resilience* reflects regions' total recovery relative to the pre-pandemic level. We compute *total resilience21* as the percentage change in real GDP between 2019 and 2021, and *total resilience22* as the corresponding change between 2019 and 2022.

All resilience variables are computed as z-scores, with respect to the country average and standardized by using cross regional (country level) standard deviations. As such, positive (negative) values indicate regions performing relatively better (worse) than the country average. While standardizing resilience scores within each country allows us to capture relative regional performance, this approach necessarily abstracts from cross-country differences in exposure to macroeconomic shocks. For example, during the COVID-19 pandemic, Italy implemented one of the strictest lockdowns in Europe, leading to a sharp contraction in national GDP, while Sweden adopted a much more lenient approach, resulting in milder immediate economic effect. Standardising regional values using the national average effectively removes this national-level variation, which means that an Italian region performing less poorly than the national average may receive a positive resilience score, even if absolute performance was weaker than a Swedish region with a below-average national score. In this sense, our standardized resilience variables are to be interpreted as measures of regional resilience in relative terms, rather than as cross-country comparable metrics of absolute resistance or exposure.

Our multidimensional Left Behindness (LB) index is constructed as a composite indicator of standardized z-scores. Positive (negative) values indicate regions that are relatively more (less) left behind compared to the national average. The index is constructed using ten sub-indicators that capture multiple dimensions of their socio-economic disadvantage: per capita income and its growth, population and employment growth, industrial employment growth, poverty, demographic structure (shares of older and younger groups), net migration and travel time to service sector. The data were drawn from the dataset by Veltuis et al. (2025)². A 6-step procedure is used to construct the index, with details provided in Table 2.

We include several control variables in our analysis. *Sectoral Diversity* is measured as the difference $(1 - HH)$, where *HH* refers to the Herfindahl-Hirschman Index defined as follows:

$$HH = \sum_{i=1}^{10} (s_i)^2 \quad (1)$$

² This dataset is publicly available at: <https://www.tandfonline.com/doi/suppl/10.1080/00343404.2024.2417704?scroll=top>

where s_i is the employment share of sector i in the region (Herfindahl, 1950; Hirschman, 1964). It captures economic variety in a region and serves as an indicator of its capacity to buffer against sector-specific shocks. In other words, a diverse industrial structure is likely to mitigate the impact of negative disruptions, as different sectors can compensate for each other's downturns (Malizia and Ke, 1993; Duran and Fratesi, 2023; Duran et al. 2024; Breathnach et al., 2015).

Industrial structure is proxied by the share of employment in industry. The industrial sector is known to be cyclic, as it is credit-dependent and highly responsive to shifts in monetary and fiscal policies, as well as to costs and demand externalities (Carlino et al., 2013; Owyang and Wall, 2009; Rodríguez-Pose and Fratesi, 2007; Değerli-Çifçi and Duran, 2025a; Değerli-Çifçi and Duran, 2025b). We further control for region's exposure to global shocks with a *trade-tourism* variable, which captures the extent to which regional economies are integrated into global markets via trade of goods and services, and input-output linkages (Hudson, 2010; Pickles and Smith, 2011; Eraydin, 2016; Gajewski, 2022). *Public employment*, which is suggested to provide a form of economic shelter, protecting regions from business cycle downturns (Rodríguez-Pose and Fratesi, 2007). Finally, the *population size* is included to capture the impact of urbanization and agglomeration (Dijkstra et al. 2015; Eraydin, 2016).

The following OLS-Newey-West type HAC (Heteroskedasticity Autocorrelation Consistent)³ regression models are estimated:

$$Resilience_i = \phi + \beta LB_i + \delta Z_i + u_i \quad (2)$$

where the dependent variable is respectively resistance, recovery or total resilience, while LB_i is our variable of interest and denotes the multidimensional Left Behindness index in region i . Z is a set of control variables including *Population*, *Sectoral Diversity*, *Industry*, *Trade-Tourism* and *Public Employment*. To account for the heteroskedastic nature of errors, Newey-West type HAC (Heteroskedasticity Autocorrelation Consistent) covariance estimates are employed (Newey and West, 1987). The results of our model are to be interpreted as correlations rather than causation, as we do not correct for possible endogeneity issues as there is an insufficient number of instrument variables at the NUTS-3 regional level. In this sense they are exploratory.

4. Results

³ The following software was used in the implementation of the empirical analyses: Eviews 4 (Micro Software LLC, 2002) and Datarwapper GmbH () for the visualisation of the maps.

The geographical distribution of resistance, recovery and total resilience across NUTS 3 EU regions (Figure 2) has some interesting patterns. Starting from panel *a* on resistance, it appears that rural or inner regions of Spain, France, Eastern Germany, North of Sweden and Finland were quite resistant. By contrast, recovery was better in more advanced regions in Northern Italy, Southern Germany and Eastern Spain (Figure 2, panels *b* and *c*). As for total resilience between 2019-2021 and 2019-2022, there is no distinct spatial pattern (Figure 2, panels *d* and *e*). This result is plausible as the total resilience is a combination of resistance and recovery which, as we saw, move in opposite directions.

- Insert Figure 2 about here -

Regarding the multidimensional LB index used in our analysis, Figure 3 plots the Kernel (LOESS) regression between the GDP-based indicator of LB versus the multidimensional LB indicator (Cleveland 1981; Fan and Marron, 1994; Fan and Gijbels 1996). Although the two measures seem similar, there are substantial differences between them with regions classified as left behind according with the GDP-alone criterion, but not with the multidimensional index (and vice versa).

- Insert Figure 3 about here -

The spatial patterns of the multidimensional LB index are shown in Figure 4. It should be noted that regions in Eastern Germany, Southern Italy, inner areas of Spain and France, Northern Sweden and Finland are identified as left behind. More in detail, the places with the highest values of the LB index are ITG16 (Enna, Sicily), DEE0A (Mansfeld-Südharz-Central, East Germany), ITG15 (Agrigento, Sicily), ITG14 (Caltanissetta, Sicily), DED53 (Nordsachsen, East Germany), whereas the lowest are DE211 (Ingolstadt, Kreisfreie Stadt, Upper Bavaria), ES531 (Eivissa, Formentera, Balearic Islands, Spain), FI1B1 (Helsinki-Uusimaa), FR105 (Hauts-de-Seine, Paris) and ITC4C (Milano). The latter are all areas in more advanced regions. These findings are theoretically expected and consistent with the existing literature.

- Insert Figure 4 about here -

Looking at the correlation between the multidimensional LB index and resilience was our next step. The model results are presented in Table 3. In Column 1 the dependent variable is resistance. It is interesting to note that there is a positive and significant coefficient of the multidimensional LB index. In other words, LB places are observed as relatively more resistant to the pandemic-driven

recession. Industrial diversity and public employment intensity have a positive and significant association with resistance.

- Insert Table 3 about here -

Higher resistance of LB places during the COVID-19 pandemic might be explained by several factors. The first factor can be the role of public employment as it has a positive and significant coefficient (Rodríguez-Pose and Fratesi, 2007; Fratesi and Rodríguez-Pose, 2016). Public assistance, employment in the public sector and subsidies are likely to mitigate the adverse impact of the shocks. Second, lack of specialization in left behind regions may be influential as the sectoral diversity has a positive and significant impact on resistance. This is compatible with the previous arguments of the literature, which emphasize that existence of sectoral variety might play a protective role against sector-specific shocks (Kort, 1981; Malizia and Ke, 1993).

As for recovery (Columns 2 and 3), the LB index has a negative and significant coefficient. It indicates that more advanced regions show a faster recovery, while this phase might be more challenging for left-behind places. Sectoral diversity and public employment intensity are also negative and significant. Thus, factor productivity driven by specialization and market-oriented sectors is linked to relatively faster recovery trajectories of more developed regions.

Finally, the results for total resilience are shown in columns 4 and 5. Here the multidimensional LB index has an insignificant effect. This is to be expected given that resistance (+) and recovery (-) operate differently in different territorial contexts, especially when comparing centres and peripheries.

5. Conclusions

The paper focuses on the relationship between economic resilience and LB across the EU regions. We follow a multidimensional approach to conceptualize LB and construct a LB index across the EU NUTS-3 regions. The index embeds a multivariate definition of regional weaknesses, going beyond the GDP per capita approach. Our findings show that left-behind places were relatively more successful in resisting the COVID-19 shock, while more advanced regions were better in the recovery phase. This interesting and region-specific result can be explained by the divergence in terms of international trade, public employment and industrial specialization observed across regional economies.

Our results can be useful to reflect on policies. Although left behind territories are commonly associated with welfare losses, they might be more resistant towards exogenous shocks due to their

“detachment” from business cycles, mitigating therefore the impact of the pandemic (Rodríguez-Pose and Fratesi, 2007; Fratesi and Rodríguez-Pose, 2016). Rural characteristics of these places may also contribute to this behaviour. However, these places, most likely, lack productivity that may be driven by specialization in modern sectors and digitalization, that may be supported by the central government in order to speed up recovery. On the other side, more advanced regions might be more exposed to external crises, particularly due to trade openness, as global supply chains, trade and financial linkages increase the potential exposure of these regions to the global shocks and geopolitical events.

Overall, it is clear that measuring LB is central in understanding place-specific resilience patterns, even though further empirical and theoretical studies on the topic are needed.

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Tables and Figures

Table 1: Overview of multivariate indices of “left behindness”

Reference	Geographical coverage	Scope of measure		Territorial unit	Methodology
		Dimension(s)	Indicators		
Comim et al. (2024) ⁴	Europe (EU, non-EU countries and Turkey)	Economic	GDP per capita; GVA growth rate; unemployment rate; household income	NUTS 2	Composite indicator
Connor et al. (2024)	USA	Economic Demographic Social	Unemployment rate Education level Median household income; poverty rate	Incorporated and Census Designated Places ⁵	Threshold criteria
Davenport and Zaranko (2020)	UK	Economic Demographic	Employment rate; employee weekly pay Education level; health	Lower-tier local authority ⁶	Composite indicator
Faggian et al. (2024)	Europe (EU)	Economic Social	GDP per capita; GVA growth rate; unemployment rate Poverty rate; income inequality	NUTS 2	Threshold criteria

⁴ It should be noted that the Authors also construct three other composite indicators, which are based on a selection of pillars beyond purely economic ones. For instance, the index based on the “wider” economic approach includes, besides economic indicators, the share of highly educated individuals in the region. Moreover, demographic variables and people’s perceptions are also considered according to other approaches.

⁵ These territorial units in the US roughly correspond to municipalities, classified as local administrative units (LAUs).

⁶ Lower-tier local authorities in the UK are roughly equivalent to local administrative units (LAUs) applied in the European classification. The LAU level is smaller than NUTS 3 level of regions.

Table 1: (cont.)

Reference	Geographical coverage	Scope of measure		Territorial unit	Methodology
		Dimension(s)	Indicators		
Houlden et al. (2024) ⁷	UK (England)	Economic	Income deprivation; employment deprivation	Neighbourhood ⁸	Cluster analysis
		Demographic	Education, skills and training deprivation; health deprivation and disability		
		Social	Crime; barriers to housing and services; living environment deprivation		
Jessen (2024)	Denmark	Economic	Income per capita; employment rate; employment rate in SMEs; employment in industrial sector; number of patented inventors	LAU (municipality level) ⁹	Cluster analysis
		Demographic	Population density; education level; share of population aged above 65		
Rodríguez-Pose et al. (2024)	EU	Economic	GDP per capita growth rate; employment growth rate; productivity growth rate	NUTS 3	Threshold criteria

⁷ To identify left behind neighborhood, authors consider multiple domains (represented by the selected indicators) that are covered by the Indices of Multiple Deprivation (IMD). In particular, there are 39 indicators, which are weighted and aggregated to obtain the IMD (Noble et al., 2019). More information on the IMD (year 2019) is also available at: <https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019>

⁸ In particular, the territorial unit of analysis is established at the so called Lower-layer Super Output Area (LSOA) developed by the Office for National Statistics (ONS). LSOAs are small areas covering approximately equal population size of about 1,500 residents.

⁹ Local administrative unit (LAU). NUTS 3 territorial units in the EU are subdivided into LAUs. Until 2016, there were two levels of LAUs, i.e., upper and lower levels, which were eliminated in 2017. More information is available at: <https://ec.europa.eu/eurostat/web/nuts/local-administrative-units>

Table 1: (cont.)

Reference	Geographical coverage	Scope of measure		Territorial unit	Methodology
		Dimension(s)	Indicators		
Royer and Leibert (2024)	Germany	Economic	GDP per capita; employment rate; employment share in service sector; employment share in creative industries; employment sufficiency; unemployment rate; youth unemployment rate; commuter balance	NUTS 3	Factor analysis and cluster analysis
		Demographic	Average age; life expectancy; youth migration; long- and short-term net migration; natural population change; share of population between 15-30 years; net migration of young women; workforce with tertiary education		
		Social	Average household income; share of households with low income; child poverty; teenage fertility; income tax; voter turnout		
		Infrastructural	Accessibility of supermarkets; hospital beds per 1,000 inhabitants		

Table 1: (cont.)

Reference	Geographical coverage	Scope of measure		Territorial unit	Methodology
		Dimension(s)	Indicators		
Velthuis et al. (2024)	Europe (EU-15)	Economic	GDP per capita; GDP growth rate; employment growth rate; employment share in industrial sector	NUTS 3	Cluster analysis
		Demographic	Population growth rate; net migration; share of population aged over 65; youth migration		
		Social	Poverty rate		
		Infrastructural	Travel time to shops		

Table 2: Variables' description

Variables	Definition	Data Sources
(i)	Resilience variables, all variables in this category are z-standardized with respect to national (cross regional) mean	
<i>resistance</i>	$\ln (y_{2020}/y_{2019})$ <i>y</i> : real GDP (at constant prices)	ARDECO (2025) EUROSTAT (2025)
<i>recovery21</i>	$\ln (y_{2021}/y_{2020})$	
<i>recovery22</i>	$\ln (y_{2022}/y_{2020})$	
<i>resilience21</i>	$\ln (y_{2021}/y_{2019})$	
<i>resilience22</i>	$\ln (y_{2022}/y_{2019})$	
(ii)	Left-behindness variables	
Composite Left-Behindness index (<i>LB</i>)	<p>6-step procedure</p> <p>1) The data for LB variables are obtained from Velthuis et al. (2025, Appendix A, publicly available at: https://www.tandfonline.com/doi/suppl/10.1080/00343404.2024.2417704?scroll=top) based on ARDECO (2021; 2025), EUROSTAT and ESPON data</p> <ul style="list-style-type: none"> • pc_y: "per capita Regional GDP in terms of fraction of national, 2018" (Velthuis et al. 2025, Appendix A) • Δpc_y: "growth rate of Regional GDP per capita minus the national value during , 1991-2018 (Velthuis et al. 2025, Appendix A) • ind: "change in the share of industrial employment share over the period 1991-2017." (Velthuis et al. 2025, Appendix A) • Emp: "Regional employment growth minus national value during 1991-2018". (Velthuis et al. 2025, Appendix A) • Pop: "Regional population growth minus national the value during 1991-2018" (Velthuis et al. 2025, Appendix A) • Mig: "Mean level of net migration during 2014-2019" Velthuis et al. 2025, Appendix A • Old: "65 year old population/15-65 year old population, 2018" Velthuis et al. 2025, Appendix A • Young: "The regional population for 20-24 year old group (2019) - The regional population for 15-19 year old group (2014), as a percentage of the total regional population" (Velthuis et al. 2025, Appendix A) • Poverty: "At-risk-of-poverty rate, as provided by the ESPON TiPSE project", (Velthuis et al. 2025, Appendix A.) 	<p>Velthuis et al. (2025); ARDECO (2021; 2025) EUROSTAT (2025), ESPON (n.d.)</p> <p>ESPON (2015; 2016), Royer et al. (2022), Copus (2014); Melo and Copus (2014)</p>

	<p>Copus, (2014), Melo and Copus (2014), ESPON (2015; 2016)</p> <ul style="list-style-type: none"> • Travel time: “travel time to the closest supermarket or convenience shop, calculated as in Royer et al. (2022)” (Velthuis et al. 2025, Appendix A; Copus (2014); Melo and Copus (2014); ESPON (2015; 2016); Noguera et al. (2017); Royer et al. (2022)) <p>2) The variables are converted into z-scores with respect to national (cross regional) means: $z = (x - \text{mean}(x))/\text{sd}(x)$</p> <p>3) Various variables’ Z-scores are reversed by multiplying with -1: <i>y, Δy, emp, pop, mig, young</i></p> <p>4) The z scores are re-scaled by adding “10” in order to maintain positive domain</p> <p>5) Geometric average of z-scores in step 4 are calculated</p> <p>6) Z-transformation applied to final composite LB index</p>	
(iii) Control variables (for the year 2019)		ARDECO (2025) EUROSTAT (2025))
Population (POP)	ln(population)	
Sectoral Diversity (DIV)	1-HH, HH. Herfindahl-Hirschman Index: $A = \sum_{i=1}^{10} (s_i)^2$ s: employment share of sectors in regions (own calculation)	
Industry (IND)	ln (Share of Industry in regional employment) Industry: “Mining and quarrying, Manufacturing; Electricity, gas, steam and air conditioning supply; Water supply; sewerage; waste management and remediation activities” ARDECO (2025) EUROSTAT (2025))	
Trade-Tourism (TRD)	ln (Share of trade-tourism in regional employment) Trade-Tourism: “Wholesale and retail trade; repair of motor vehicles and motorcycles; Transporting and storage; Accommodation and food service activities” ARDECO (2025) EUROSTAT (2025))	
Public Employment (PUB)	ln (Share of public sector in regional employment) public: “Public administration and defence; compulsory social security; Human health and social work activities; Education” ARDECO (2025) EUROSTAT (2025))	

Note: each variable captures a specific dimension of left-behindness, as indicated in parentheses.

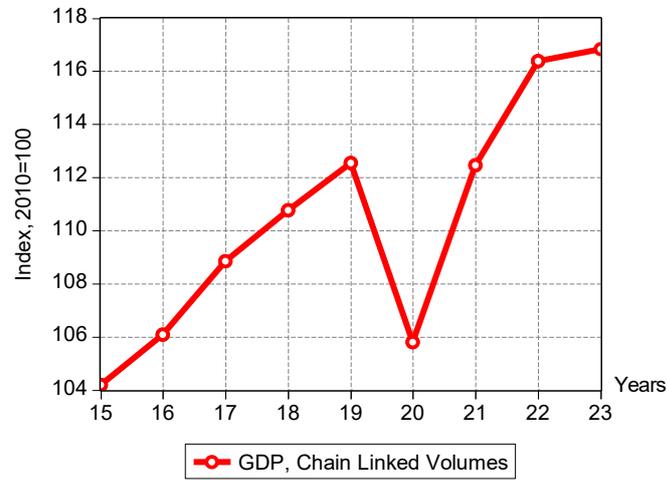
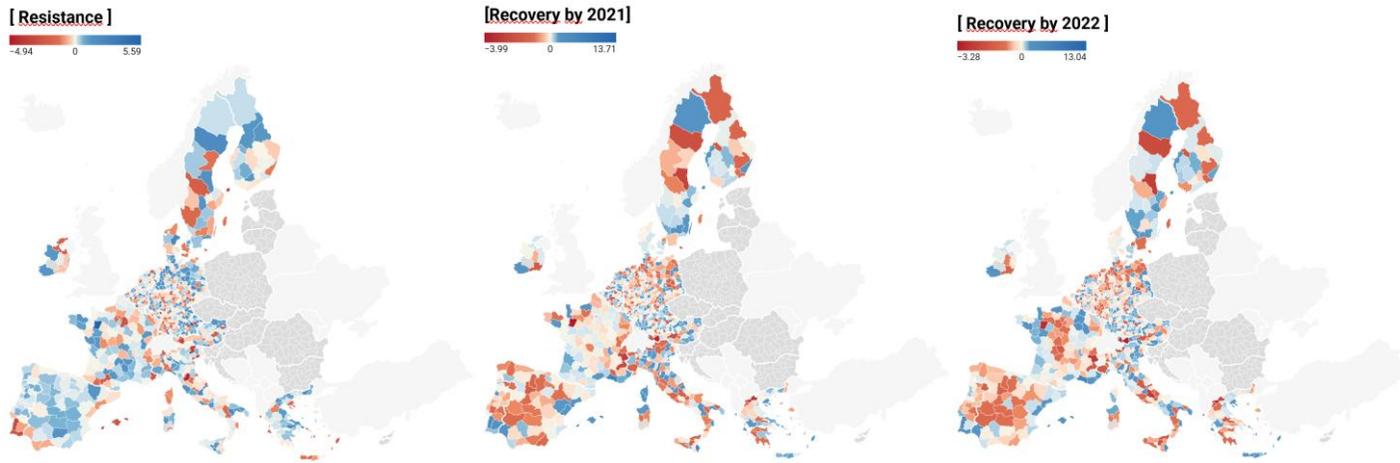


Figure 1: Real GDP in the Euro area (EA) countries

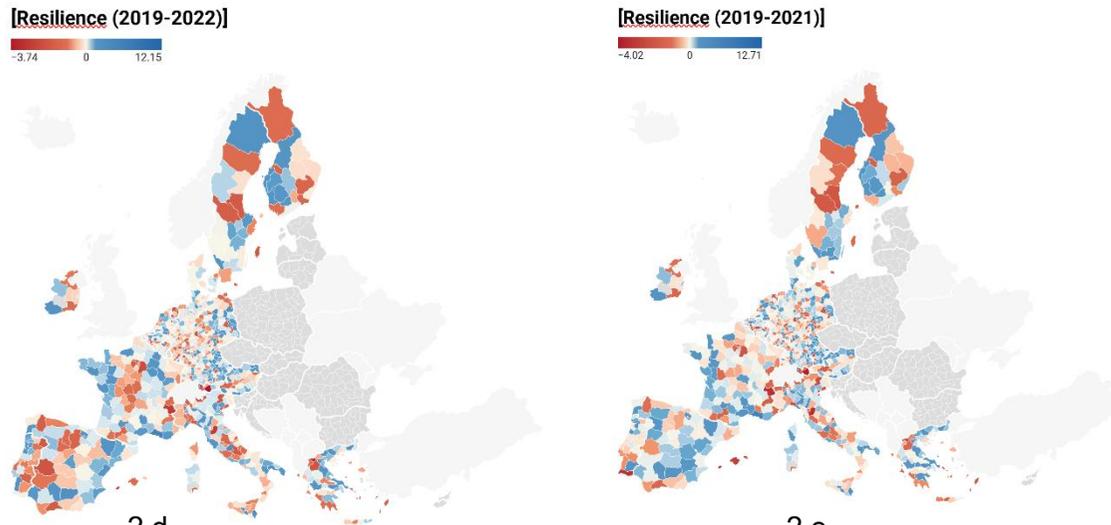
Note: authors' elaboration based on the data from Eurostat (2024). The Euro area includes the following 19 countries (2015-2022): Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Spain



2.a

2.b

2.c



2.d.

2.e.

Figure 2: Resilience Maps, z-scores

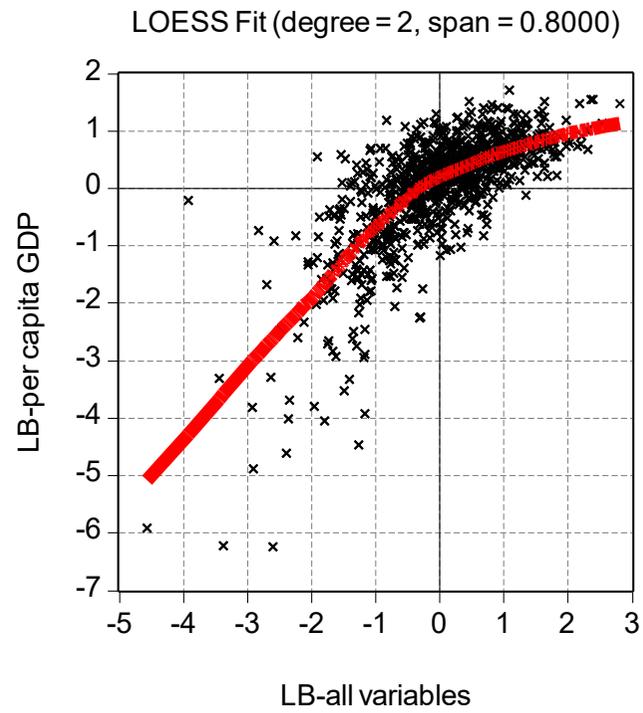


Figure 3: Multidimensional Left Behindness Index and Left Behindness based on GDP per capita (z-score)

Left Behindness Index

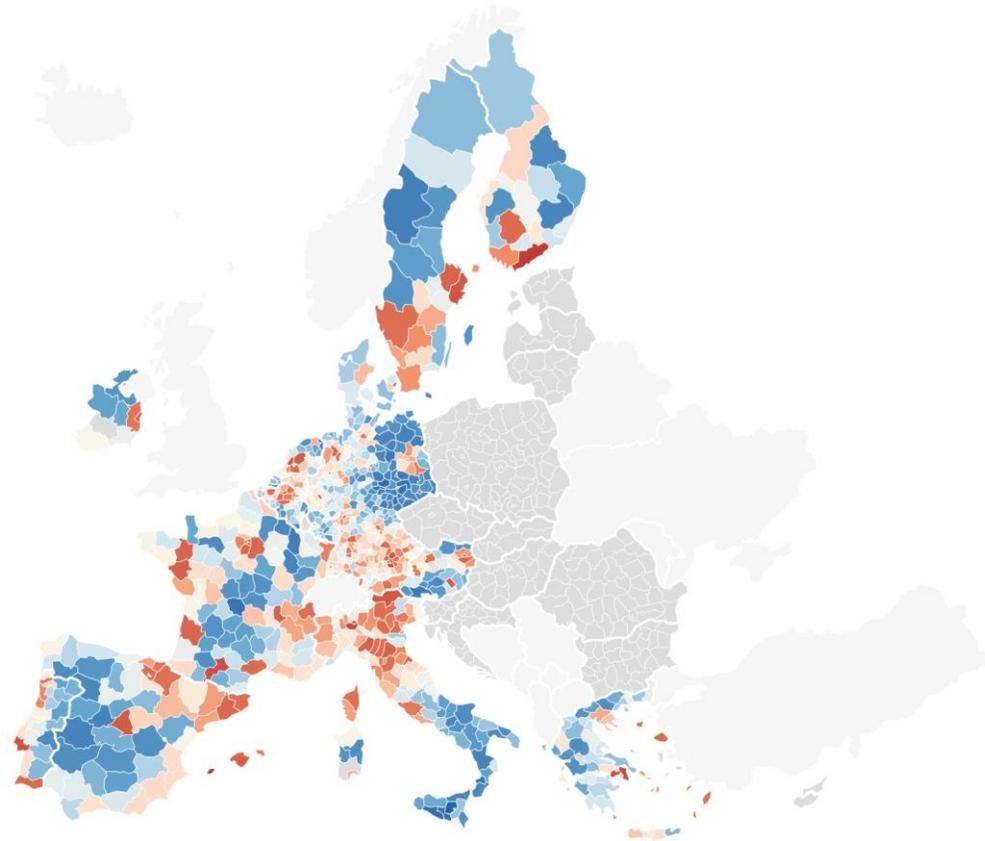
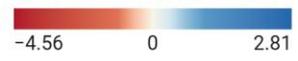


Figure 4: Multidimensional Left Behindness Index, z-scores

Table 3: Regression Results, N=898

<i>Variables</i>	<i>resilience</i>	<i>recovery21</i>	<i>recovery22</i>	<i>resilience21</i>	<i>resilience22</i>
<i>C</i>	2,383814**	-2,81766***	-3,03452***	-0,52066	-0,93094
<i>LB</i>	0,150722***	-0,14126***	-0,15797***	0,039062	-0,01592
<i>POP</i>	-0,02902	0,055741	0,070692	0,043746	0,060279
<i>DIV</i>	8,505983***	-3,57196***	-4,14324***	4,752412***	3,677771***
<i>IND</i>	-0,05363	-0,05233	-0,05715	-0,03794	-0,05558
<i>TRD</i>	-0,19754	-0,41812	-0,32708	-0,58921**	-0,46879*
<i>PUB</i>	0,397503*	-0,46015**	-0,48144**	-0,06502	-0,1451
<i>Newey-West Standard Errors</i>	Yes	Yes	Yes	Yes	Yes
<i>F-Stat</i>	19,29***	7,42***	9,76***	6,81***	4,18***
<i>N</i>	898	898	898	898	898

Note:*** significance at 1%, ** at 5 %, * at 10%.