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Lost in transition? Trajectories of regional 'left-behindness' in the EU15 from 1982 to 2017

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Lost in transition? Trajectories of regional 'left-behindness' in the EU15 from 1982 to 2017

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Abstract

'Left behind places' have received increasing attention in the Global North, acknowledging growing regional inequalities between and within countries. Yet the trajectories followed by these places have mostly been investigated by assessing changes between two time-points. Addressing this, we combine k-means clustering and sequence analysis to study detailed regional trajectories between 1982 and 2017 for EU15 NUTS3 regions. The resulting typology of trajectories evidences how some regions have increasingly or more recently 'fallen behind', some have remained 'left behind', and still others have experienced overall positive decades, at least temporarily catching-up on wealthier regions. As such, our findings suggest different transitions in and out of 'left-behindness'.

Keywords

'left behind' places, regional inequalities, regional trajectories, divergence, peripheralisation, sequence analysis

JEL codes

R11, R12, N1

1. Introduction

A versatile phrase, the term 'left behind places' is now widely used in scientific and political debates to identify territories whose development has been minimal, halted or significantly slowed down in some way, particularly since the financial crisis of 2007–2008. These places are then considered 'left behind' relative to other more dynamic areas, the conceptual opposite of "superstar cities" (Le Galès & Pierson, 2019). Building on existing terminology regarding spatial "convergence" and "divergence", "gaps" or "imbalances" (Alonso, 1968; Leibenath, 2008; Maillat & Lecoq, 1992), the concept of 'left behind places' assembles various dimensions under the same shorthand. It thus goes beyond economic decline to "encompass social, demographic, political and cultural concerns" (MacKinnon et al., 2022).

Growing inequalities between 'left behind' and more succesful places, combined with a sense of abandonment by political and economic elites, is often expressed by citizens through growing support for populist parties and movements (Bjornsson & Zoega, 2018; Dijkstra et al., 2020; Krouwel & Abts, 2007). Beyond the injustices of the moment, concerns voiced by inhabitants of 'left behind places' stem in part from a sense that their relative position in society has declined over time (Baccini & Weymouth, 2021; Essletzbichler et al., 2018; Rodríguez-Pose et al., 2021). Thus, while recent demonstrations of discontent have often crystalised around current issues, they also appear to be a by-product of medium- or long-term spatial divergence. Yet the trajectories followed by 'left behind places' have thus far not been subject to much dedicated analysis. To the extent that existing work focuses on understanding the longer-term change that has occurred in 'left behind places', it tends to analyse this change in a fairly simplistic way by analysing growth or decline between two time-points.

Addressing the empirics of 'left-behindness'[1], this paper is designed to illuminate the dynamics of regional change across the EU15 by studying NUTS3[2] regions' trajectories from 1982 to 2017. Advancing beyond the observation between two time-points, our work highlights the extent to which these regions experienced different development pathways and how this can be put into perspective in terms of 'left-behindness'. More specifically, we identify when the process of 'falling behind' takes place for different regions and how different dimensions of 'left-behindness' contribute to defining various transitions. Borrowing our core methodology from neighbourhood-focused studies and implementing our own refinements, k-means clustering and sequence analysis are used to create a typology of regional trajectories.

The next section provides an overview of the literature on the dynamics of 'left-behindness' and how it has shaped our own approach. The data and methods are presented in Section 3 and we review our results in Section 4. We then discuss our findings in Section 5, before concluding the paper in the final section.

2. Becoming 'left behind': key aspects of change

While the trajectories of 'left behind places' have been subject to little explicit analysis, the literature does recognise the importance of temporal change in their characterisation (Iammarino et al., 2020; Rodríguez-Pose, 2018). This has led to identification of the changes undergone by these areas over different dimensions and horizons, going beyond a strict cross-sectional observation. We provide an overview of these findings in a first subsection, as they offer important foundations for alternative research questions regarding the dynamic aspects of 'left-behindness', which are presented in a second subsection.

Changes experienced by 'left behind' places

Identifying relatively short-term changes is the most frequent way of studying the temporality of 'left-behindness'. This approach has generated multiple concepts and measures in the literature, each defining dynamic processes associated with various dimensions of 'left-behindness'.

The economic dimension is the most widely discussed in the literature. Economic geographers identify different forms of economic decline or low growth as characteristic of struggling areas, without necessarily labelling them as 'left behind places'. This includes macroeconomic measures of economic output, such as change in GDP, for example used to identify 'lagging regions' below a certain threshold of economic growth (Farole et al., 2018; Pilati & Hunter, 2020), or to discuss regional convergence both within countries and across Europe, following the convergence objective of the European cohesion policy (Bourdin, 2013; De Michelis & Monfort, 2008; Goecke & Hüther, 2016). Other economic aspects are also investigated, such as productivity, innovation and human capital, sometimes introducing micro-level measures, e.g., household income (Diebolt & Hippe, 2016; Doran & Jordan, 2013; Isaksen et al., 2018).

Other forms of economic change traditionally associated with 'left-behindness' are specific shifts in the labour market, not only in total employment but also in terms of sectoral composition. Particular emphasis is placed on unsuccessful transitions to a post-industrial service economy as a recurring factor in becoming economically 'left behind', especially in relation to superstar cities gathering high-skilled activities. While deindustrialisation may indeed be part of a process of replacement of activities by more productive ones, further investigations have shown that (1) not all territories have benefited equally from these changes (Birch et al., 2010; Hobor, 2013; Pike, 2022) and (2) the activities replacing traditional manufacturing have been variably beneficial in terms of quality of employment (McMillan et al., 2014). Regarding sectoral dynamics, authors in the field of evolutionary economic geography highlight the role of existing firm-level structures, as well as public and private actors in shaping and reshaping sectoral specialisation, leading to positive or more mixed regional outcomes (Cortinovis et al., 2017; Elekes et al., 2019; Neffke et al., 2011).

As mentioned previously, the dynamic aspects of 'left-behindness' are not limited to economic changes. Demographic decline is another dimension often considered as a key feature of ‘left behind places’, as it reveals regional depopulation both in rural territories (Amcoff & Westholm, 2007; Copus & de Lima, 2014; Li et al., 2019) and, more recently, in urban areas, where it is associated with so-called “shrinking cities” (Béal, Cary, et al., 2019; Cauchi-Duval et al., 2016; Wolff et al., 2013). While population loss can occur through both natural and migratory processes, it differs in form and intensity with specific combinations of the two when studying regional dynamics (Haase et al., 2016). More than at national level, the demography of a region is much more sensitive to selective out- (and/or in-) migration, which in turn modifies the natural renewal of its territory. Selective migration results from the economic and social characteristics of the region, attracting or repelling specific categories of inhabitants. This then modifies the regional demand for certain facilities and services, which may eventually lead to their scarcity or even disappearance at the local level, potentially reinforcing selective migration (Franklin, 2021; McCann, 2017). Through these circular processes it can generate, the literature thus emphasises that “population loss is both outcome and process” (Franklin, 2020).

Combining the economic and demographic dimensions with social and political processes, the concept of peripheralisation explains how certain territories are progressively sidelined, or ‘left behind’, from core urban areas (Kühn, 2015; Lang, 2012; Liebmann & Bernt, 2013). Although this process is usually visible in geographically remote peripheries or ruralities, (Leibert, 2013; Leibert et al., 2015), researchers also identify forms of peripheralisation in less remote areas, namely inner peripheries (Noguera et al., 2017; Pérez-Soba et al., 2012). Following its definition in the literature, peripheralisation works through four key processes (Kühn & Weck, 2013). The first and most central one is population loss and/or ageing through out-migration, as discussed above. The second is that of economic difficulties, notably through the de-coupling from (1) innovation networks that may distance local actors from clusters of advanced knowledge and (2) infrastructures, reducing access to employment and services. The third key process characterising peripheralisation is a growing dependence on external actors, particulary large companies and regional and national governments (Manfred & Matthias, 2013). The fourth element of peripheralisation is stigmatisation, either by external media that define a territory as struggling, or by its own residents who progressively embody these forms of local marginalisation in a kind of self-fulfilling prophecy (Chavarria Devia, 2020). By grouping these different dynamics under one overarching process, peripheralisation emphasises how endogenous and exogenous factors contribute to regional ‘left-behindness’ and how interconnected they are (Leibert & Golinski, 2016).

Among other changes, assessing economic decline, population shrinkage or peripheralisation has proven useful in understanding how ‘left-behindness’ is spatially and temporally unfolding. However, in practice this is usually done by measuring changes between two points in time, rather than by exploring the temporality of processes in more detail. Although it remains overlooked, this type of approach can be found in some existing work, which we present below.

Temporary, permanent, irreversible? The trajectories of ‘left-behindness’

European regions that have undergone the most pronounced negative trends since 1980 are not necessarily those found at the bottom of the current distribution, for example in terms of economic changes (Kilroy & Ganau, 2020). This then introduces the topic of the trajectories of ‘left behind places’, the successive phases they experienced and to which extent ‘left-behindness’ is “temporary or permanent” (Pike et al., 2022). Going back to the etymology of the term, we argue that, for an entity to be ‘left’ behind, there must be points in time when it had a chance not to be. This is at odds with the idea of a strictly permanent condition, and motivates efforts to understand when and how the process of ‘falling behind’ takes place for different regions.

Long before the adoption of the ‘left behind’ terminology, the idea of studying regional trajectories in Europe was already present in the literature. From the mid-1970s onwards, the approach was mainly prospective and aimed at anticipating European regional ‘convergence’, i.e., the narrowing of previously-existing gaps (Button & Pentecost, 1995). The results suggested that some economic convergence had indeed been achieved within the European Union (Canaleta et al., 2002; Neven & Gouymte, 1995), but also that the “convergence machine” eventually seemed to need an “upgrade” (Ridao-Cano & Bodewig, 2018). Moreover, the growing inequalities in Europe have gradually given rise to the concept of regional ‘divergence’, which echoes the idea of being ‘left behind’ as they both imply a widening gap between places (Fagerberg & Verspagen, 1996; Rodríguez-Pose, 1999). Despite some economic catch-up from new entrants to the European Union, the literature identifies different development pathways between the ‘Old’ and the ‘New’ Europe (Dunford & Smith, 2009).

Informed by the findings on regional convergence and divergence, scholars proposed concepts encompassing both multi-dimensionality and temporality of uneven development. Distinct from more ‘static’ understandings such as “backward regions” (Cappelen et al., 1999), more dynamic concepts like regional "resilience", "lock-in", "middle-income trap" or "path-creation / dependency" incorporate an implicit idea of regional trajectories (Iammarino et al., 2020; MacKinnon et al., 2019; Martin & Sunley, 2006; Martinelli & Novy, 2013). The 'lagging regions' category is another example, as it includes both ideas of 'being behind' at some point in time and 'staying behind' as a continuum.

We argue that defining these dynamics requires the identification of short-term changes within an overarching longer timeframe. Only a few papers take this route. For example, shifts from convergence to divergence and various trajectories of changes in wages are identified in the United States (US) and Europe (Kemeny & Storper, 2022; Martin et al., 2021), and three types of pathways of decline are proposed as a glimpse into the "dark side" of industrial development (Blažek et al., 2020). Work that aims to characterise more specifically the trajectories of territories through the prism of 'left-behindness' is more often conducted at the neighbourhood level (Delmelle, 2017; Delmelle et al., 2013; Lee et al., 2017). The use of specific methods in this research addresses the question of whether there are other pathways outside the upgrading/downgrading dichotomy, and going beyond "investigating snapshots of change between two points in time" (Delmelle, 2016). Authors thus identify different predominant pathways of neighborhood change in the US, while emphasizing how many are characterized by stability (Delmelle, 2017; Wei & Knox, 2014), or highlight various patterns of socio-economic progress or decline in Britain (Patias et al., 2021).

Building on these neighbourhood-focused studies, we undertake a similar trajectories analysis at the regional scale. Beyond simply identifying different types of 'left behind places', our study creates a typology of various regional trajectories and shows how different dimensions of 'left-behindness' are involved, navigating the conceptual and technical challenges of such an approach.

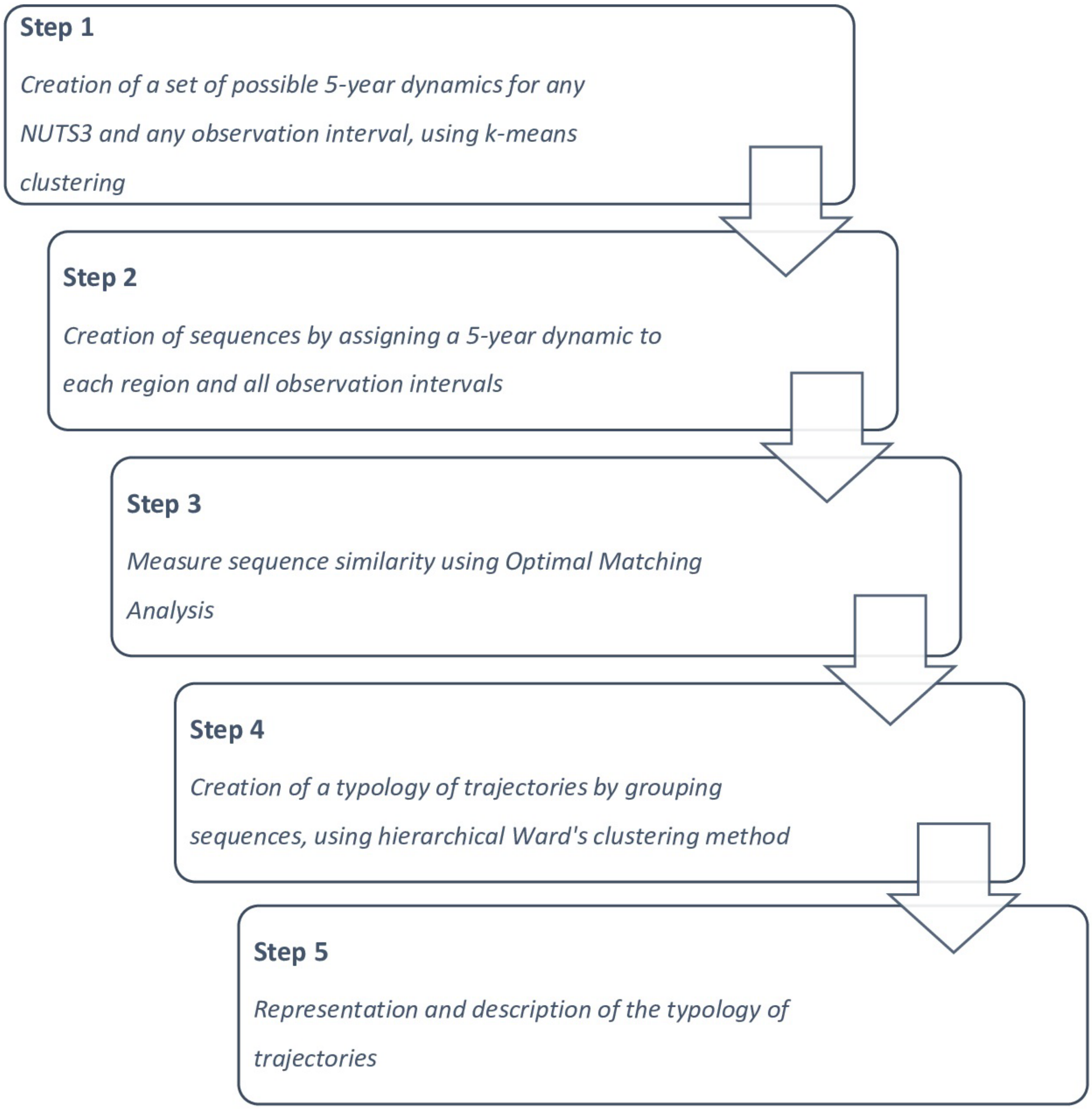
3. Methods and data

The use of 'conventional' dynamic measures between two distant points in time do not tell much about patterns of change between these dates. Observing a similar downward trend between two dates can either relate to continuous decline or to recent recovery from a past decline, which can convey different conclusions regarding regional development[3]. To address this, we generate a typology of trajectories by considering observations over time within a sequence analysis, for the EU15 NUTS3 regions and from 1982 to 2017. Combining demographic, economic, and sectoral indicators, we assess different possible short-term changes for these regions over 5-year intervals. We then analyse the sequences constituted by the successive 5-year dynamics and group together regions that experienced similar sequences.

Step-by-step methodology

In order to meet our objectives, we combine k-means clustering and optimal matching (OM) analysis. It is a 5-step protocol, schematically presented in Figure 1. This approach leads us to analyse trajectories over 7 intervals of 5 years between 1982 and 2017[4] in order to provide as much detail as possible.

Figure 1: Analysis protocol



Source: Developed by authors.

Step 1 is dedicated to identifying a set of possible 5-year short-term dynamics[5] for any region during any interval. To do so, we measure, for each region and for each 5-year period, the degree of change experienced on a number of indicators (more information on input variables below). We then use cluster analysis to categorise each region-period pair into one of a number of clusters. After ensuring consistency of results[6], the usual decision tools[7] tend to suggest a 7-cluster solution as the optimal compromise. Tests show that the added value of additional clusters did not outweigh the difficulties they introduce in the subsequent steps of the analysis. During Step 2, a sequence consisting of seven successive spells of 5-

year dynamics is assembled for each NUTS3 region. This results in 954 unique sequences for 1,021 regions, i.e., relatively few strictly identical trajectories of seven 5-year dynamics[8]. These sequences are then grouped into a typology of trajectories, which involves Steps 3 and 4 of our protocol. Regarding Step 3, we choose to measure the (dis)similarity between sequences using optimal matching (OM) analysis. A key advantage of this method is that the user can define OM costs specific to the research object. Here, substitution costs are derived from transition rates between clusters and the indel cost is set at half the maximum substitution cost[9]. In the fourth step of our protocol we use hierarchical Ward's clustering to group trajectories, a method that has often been used in social sciences (Robette, 2011). Following the usual quality indicators[10], we thus end up with a typology of seven groups of trajectories that we describe and analyse in Step 5.

Although different methods are relevant for information synthesis, such as self-organising maps (Delmelle et al., 2013) or alternative measures of similarity between sequences (Delmelle, 2017), our methodology is in line with the developments of the last few decades about neighbourhood trajectories and in the fields of life course analysis and event history analysis (Billari, 2001; Courgeau, 1989; Willekens, 1999) and about neighbourhood trajectories. We thus suggest that combining k-means clustering and OM analysis addresses the empirics of 'left behind places' by apprehending, for each region, the "whole trajectory as a conceptual unit"[11] (Robette, 2011). However, the implementation of this innovative methodology comes with its challenges, especially in terms of data.

Data and input variables

To meet our various constraints, we work with data from the Annual Regional Database of the European Commission's Directorate General for Regional and Urban Policy (ARDECO). The database contains a variety of regional indicators geographically harmonised at the NUTS3 level, for the period 1980 to 2017.

As mentioned previously, the 'left behind' category is so broad that it "hides and simplifies rather than exposes and illuminates" (Pike et al., 2022). Our aim is therefore not to be exhaustive in terms of the aspects and types of 'left-behindness' we consider, but rather to use indicators that highlight phenomena that echo the broader concept. Although limited, our set of input variables covers a common core of existing definitions regarding 'left-behindness'. Given how data-demanding our methodology is and the availability and quality of the ARDECO data, a set of demographic and economic indicators were finally selected.

Whether linked to out-migration or to the non-renewal of an ageing population, population loss is characteristic of a form of abandonment and non-attractiveness of a territory and refers to the processes of peripheralisation and urban shrinkage (Béal, Cary, et al., 2019; Cauchi-Duval et al., 2016; Leibert & Golinski, 2016). Although there are several forms of population shrinkage (Haase et al., 2016), the data available do not allow us to detail these dynamics, for example by breaking down the population by age.

Secondly, the ARDECO database offers several indicators measuring the economic dynamics of the region. We use growth in GDP per head to measure the general economic dynamics of the region (Noguera et al., 2017; Pilati & Hunter, 2020). We also use growth in total employment as a measure of the dynamics of the local labour market, as well as employment in certain sectors linked to key phenomena mentioned previously, such as deindustrialisation and the tertiarisation of activities (Dijkstra et al., 2020; van Neuss, 2018).

Conceptual and technical considerations[12], as well as various preliminary tests, have therefore led us to a compromise between exhaustiveness and interpretability. A summary of our input variables is presented in Table 1.

Table 1: Input variable summary

Dimension	Input variable	Relative to country level
Demography	Growth rate of total population	Yes
Economy	GDP per head	Yes
	Growth rate of the GDP per head	Yes
	Growth rate of total employment	Yes
Sectoral structuring	Change in the industrial sector as a share of regional employment	No
	Change in the financial and business sector as a share of regional employment	No
	Change in other activities as a share of regional employment	No

Source: Authors' analysis based on ARDECO data.

As several options were available, the timeframe of analysis was carefully chosen to consider the particular events that the study area may have encountered during specific periods. For instance, understanding deindustrialisation in the European Union differs before and after 1995 with the entry of the 'new' member states alongside the 'old' ones (Smith et al., 2001), as do the employment dynamics before and after the 2008 financial crisis (Fratesi & Rodríguez-Pose, 2016). As a result, we favour the longest possible observation period to study the most extensive and detailed trajectories. Geographically, while comparing very fine units on a large scale such as the EU15 may appear promising, it remains important to work with territories that are large enough to allow the observation of meaningful changes.

These considerations have led us to study regional trajectories at the NUTS3 level and between 1982 and 2017. Consequently, we obtain a database of 1,021 regions in the EU15 countries[13].

4. *Results*

Our analysis produces two sets of results. The first is the clusters of region-period pairs with similar magnitudes of short-term changes. We obtain a set of what we call 5-year dynamics which are the different different types of changes that any region might experience during any 5-year observation interval. Although it contains interesting findings regarding short-term dynamics, this first output is mainly a tool to construct the sequences or trajectories, consisting of seven successive 5-year dynamics for each region. The second set of results is the typology of trajectories that we then construct by grouping these sequences. It consists of seven groups of trajectories sharing similar profiles of successive 5-year dynamics. This typology is our main result, allowing us to identify and describe the different pathways of EU15 NUTS3 regions between 1982 and 2017.

Sets of 5-year dynamics

The changes identified by each cluster of 5-year dynamics are presented in summary form in Table 2.[14]. The cluster names aim to highlight key aspects of the dynamics in a practical way for the next steps of the analysis. Similarly, the cluster descriptions are indicative of general trends, bearing in mind that a significant within-cluster heterogeneity may remain. A region may thus have experienced a particular phenomenon without necessarily being assigned to the cluster that seems to be most characteristic of it, especially if it has simultaneously experienced other dynamics in an even more pronounced way. The clusters are ordered following two rules. First, even if we avoid dichotomising clusters into a strict division between 'left behind' and 'not left behind' ones, some clusters do seem more indicative of overall favourable or unfavourable 5-year dynamics. As a result, the first three clusters represent relatively positive dynamics, while the last four do appear more indicative of being or becoming 'left behind'. Considering that clusters relate to various changes, both in terms of intensity and dimension, ranking them further within these two broad types of 5-year dynamics would have been difficult, especially when trying to order them as more or less 'left behind'. Within the two broad types, the clusters are therefore ordered from those with the most region-period pairs to those with the fewest within our two broad types of 5-year dynamics.

Table 2: Clusters of 5-year dynamics

Key aspects: [1] Demographic and economic changes - [2] Sectoral reconfiguration - [3] Scope and temporal patterns

	Name	Description
Cluster 1	**Demographic and employment dynamism**	*[1]* Favourable dynamics led by demographic and employment dynamism, within a high initial GDP per head *[2]* Sectoral reconfiguration similar to the whole EU15 : deindustrialisation combined with growth of all other activities *[3]* 1415 region-period pairs, no specific temporal pattern
Cluster 2	**Economic dynamism and Fin & Bus growth**	*[1]* Favourable dynamics led by economic and employment dynamism, within a high initial GDP per head *[2]* Sectoral reconfiguration oriented towards the growth of the Fin & Bus sector *[3]* 765 region-period pairs, temporal concentration after 1997
Cluster 3	**Economically catching up**	*[1]* Favourable dynamics led by economic and employment dynamism, within a low initial GDP per head *[2]* Sectoral reconfiguration similar to the whole EU15 : deindustrialisation combined with growth of all other activities *[3]* 750 region-period pairs, temporal concentration before 2002
Cluster 4	**Demographic and economic relative decline**	*[1]* Unfavourable dynamics led by demographic and economic relative decline, within an average initial GDP per head *[2]* Sectoral reconfiguration similar to the whole EU15 : deindustrialisation combined with growth of all other activities *[3]* 1831 region-period pairs, no specific temporal pattern
Cluster 5	**Demographically and economically lagging**	*[1]* Unfavourable dynamics led by demographic and economic relative decline, within a low initial GDP per head *[2]* Sectoral reconfiguration oriented towards persistence of the industrial sector *[3]* 1495 region-period pairs, temporal concentration between 2012 and 2017
Cluster 6	**Economic slowing and deindustrialisation**	*[1]* Unfavourable dynamics led by economic slowing, within a high initial GDP per head *[2]* Sectoral reconfiguration oriented towards intense deindustrialisation *[3]* 675 region-period pairs, temporal concentration before 2007
Cluster 7	**Employment slowing and Fin & Bus decline**	*[1]* Unfavourable dynamics led by employment slowing, within a high initial GDP per head *[2]* Sectoral reconfiguration oriented towards the growth of other sectors than the industry or the Fin & Bus sector *[3]* 216 region-period pairs, temporal concentration between 1987 and 2002 and between 2007 and 2017

Source: Authors' analysis based on ARDECO data.

Typology of trajectories

Finally, we represent and describe these groups of trajectories for the fifth and last step of our protocol. We use various indicators and charts available in the sequence analysis toolbox, only displaying the most visual ones. First, Figure 2 highlights the geography of NUTS3 regions belonging to each group of trajectories, as well as their respective index plots and medoids (the region within each group of trajectories which can be considered most 'typical' or representative)[15]. A global overview of our typology across the EU15 is then presented in Figure 3. Groups of trajectories are labelled with short names and their ordering follows a similar logic as for the clusters of 5-year dynamics. The first two groups of trajectories therefore relate to generally favourable trajectories, groups 3 and 4 are characteristic of interrupted positive trajectories and the last three groups relate to rather continuous unfavourable trajectories. Groups are then ordered by decreasing number of regions within these three categories.

Figure 2: NUTS3 geography and index plots by group of trajectories (1/4)

Bottom panel :

Index plots by group of trajectories, presented after smoothed multidimensional scaling (Piccarreta, 2012). Reading is longitudinal, each line is a complete sequence of the seven successive clusters of changes for a NUTS3 region.

Clusters of 5-year dynamics:

- Demographic and employment dynamism
- Economic dynamism and fin & Bus growth
- Economically catching-up
- Demographic and economic relative decline
- Demographically and economically lagging
- Economic slowing and deindustrialisation
- Employment slowing and Fin & Bus decline

Source: Authors' analysis based on ARDECO data. Boundaries are from EuroGeographics.

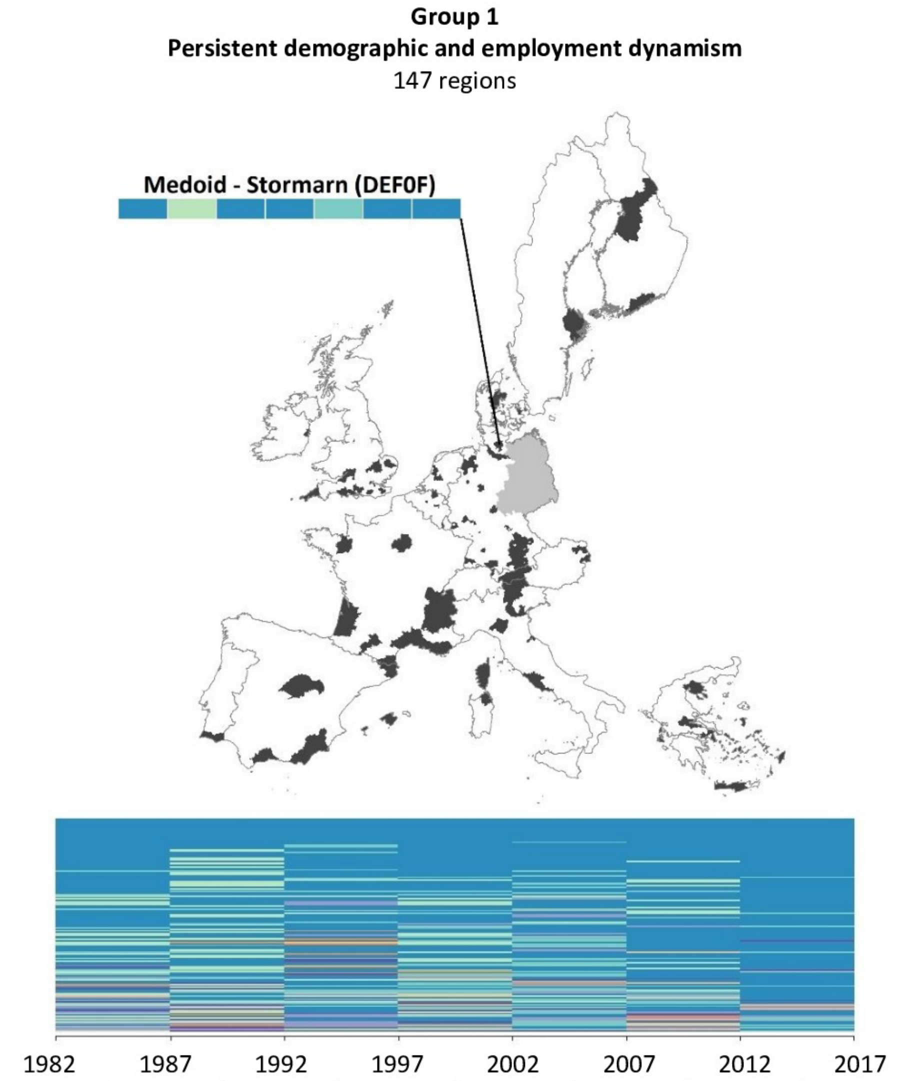


Figure 2: NUTS3 geography and index plots by group of trajectories (2/4)

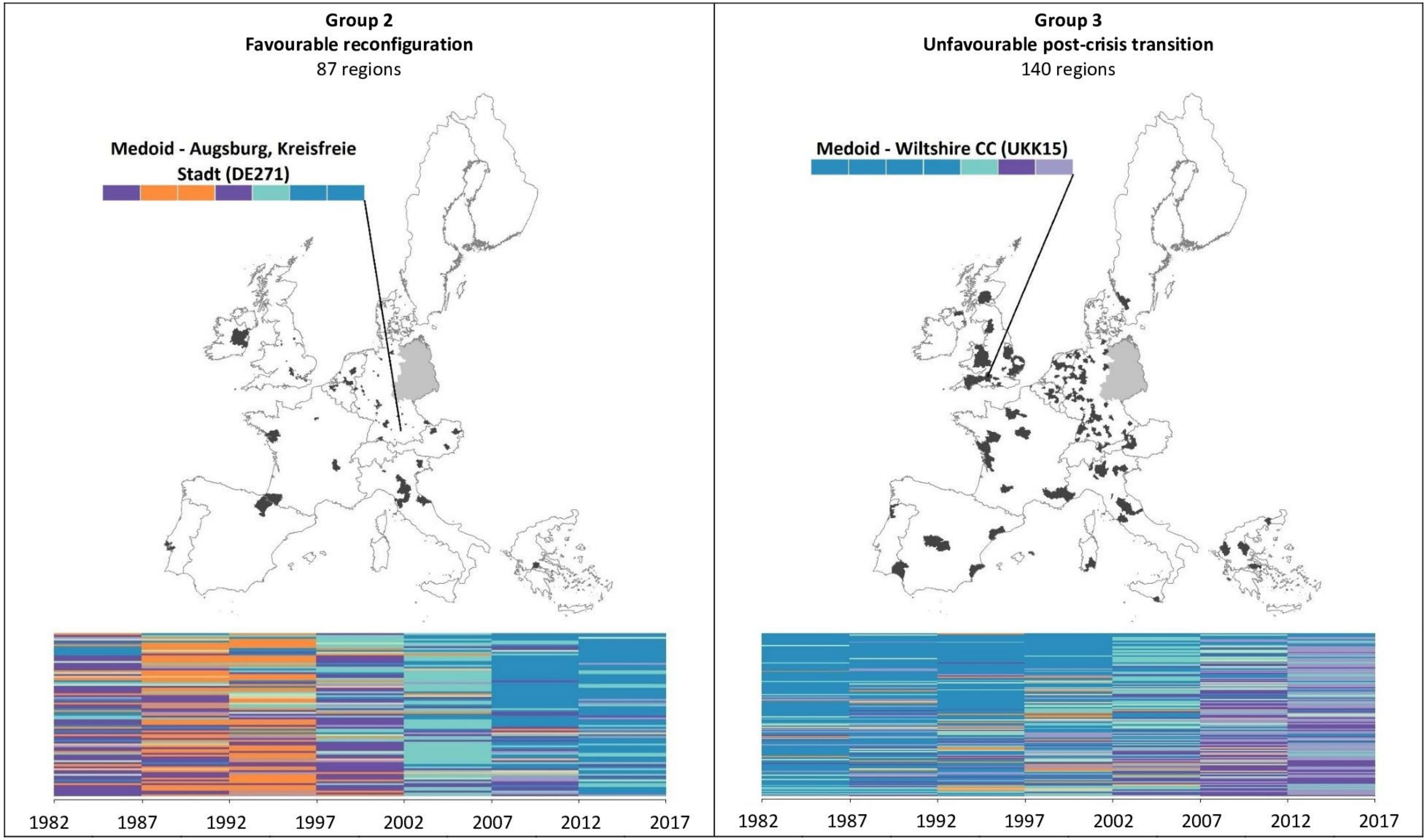
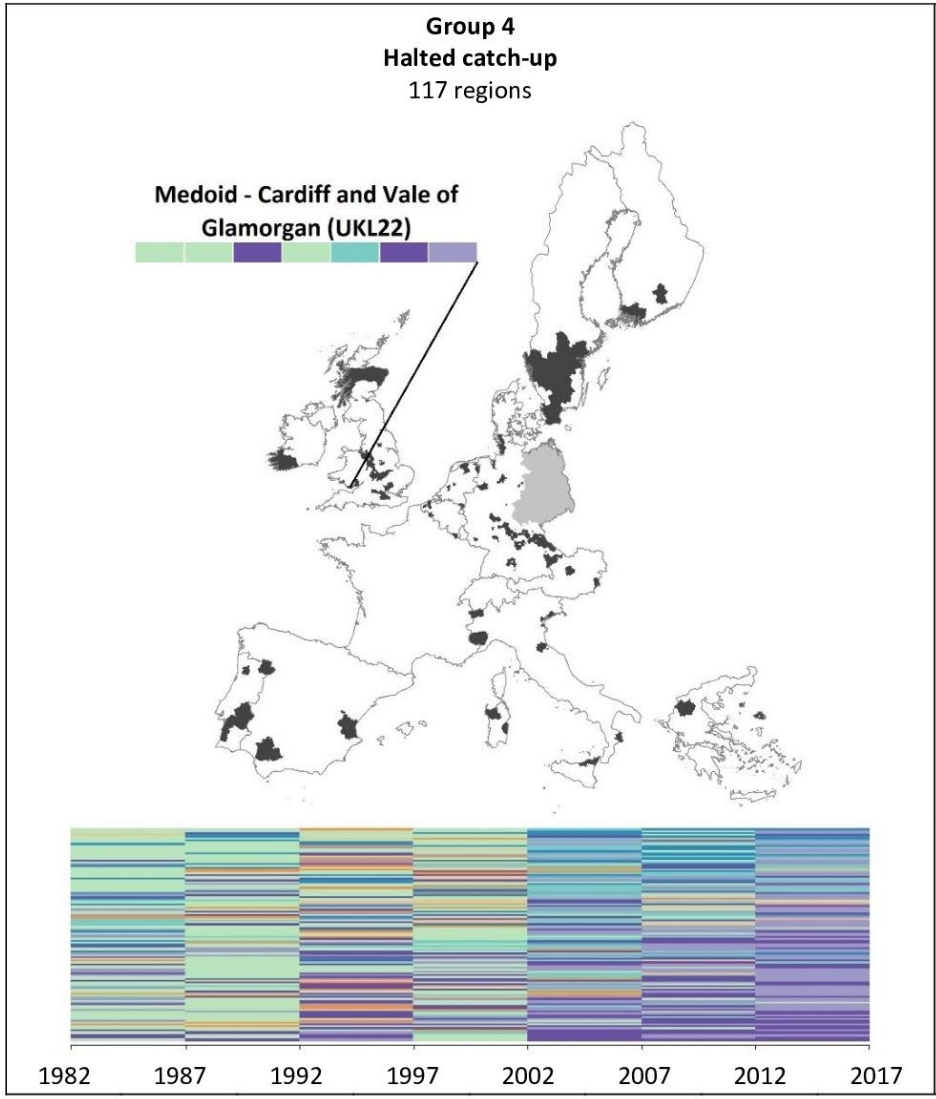


Figure 2: NUTS3 geography and index plots by group of trajectories (3/4)



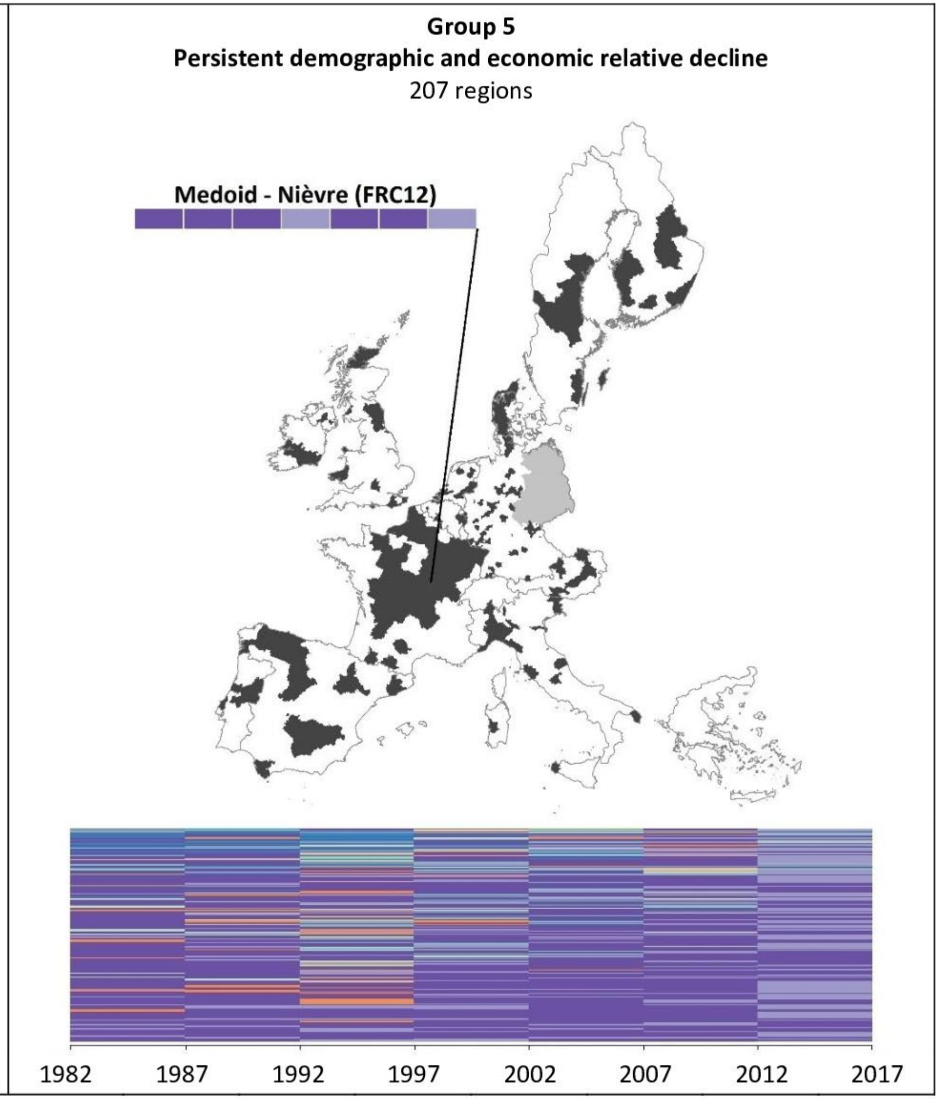


Figure 2: NUTS3 geography and index plots by group of trajectories (4/4)

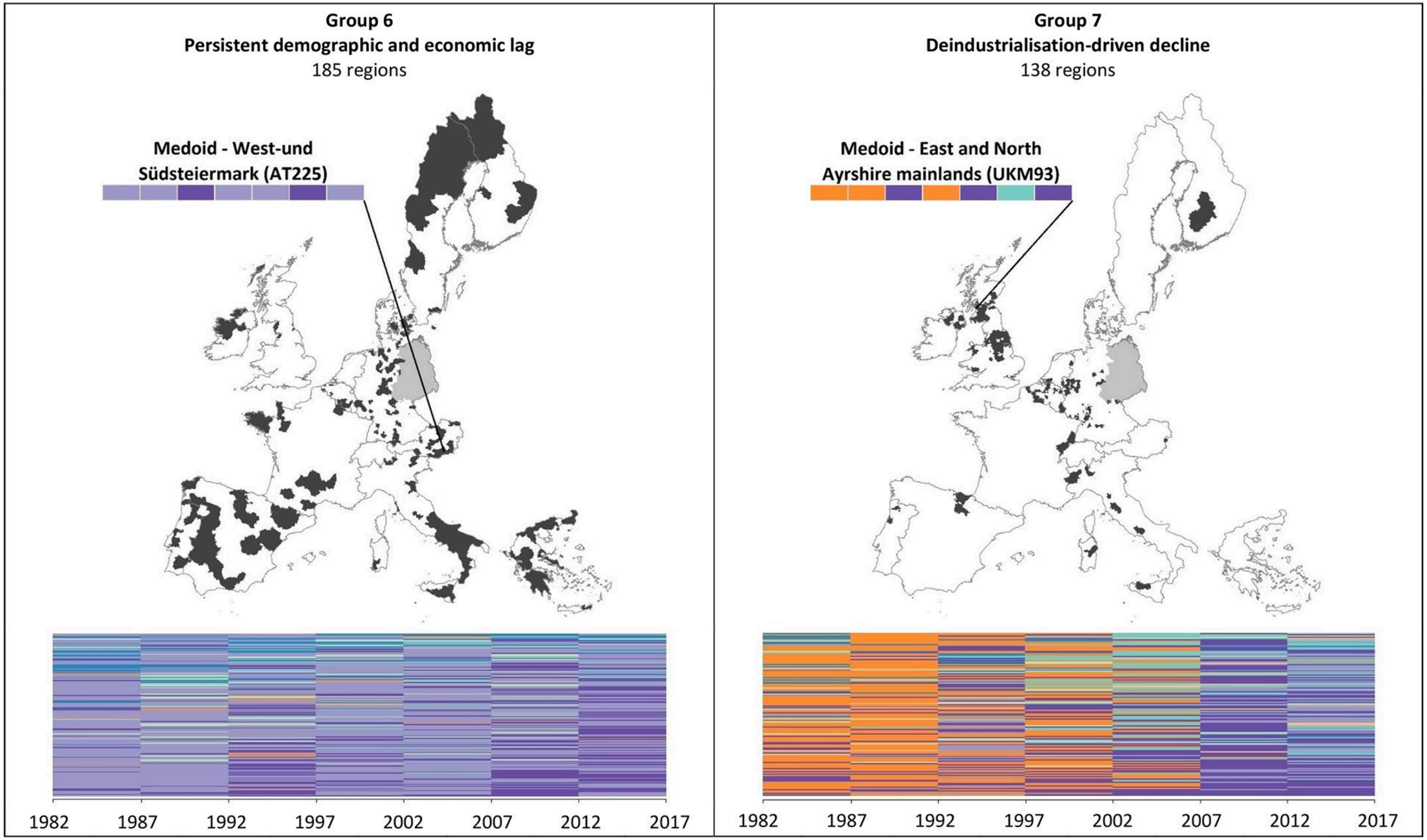
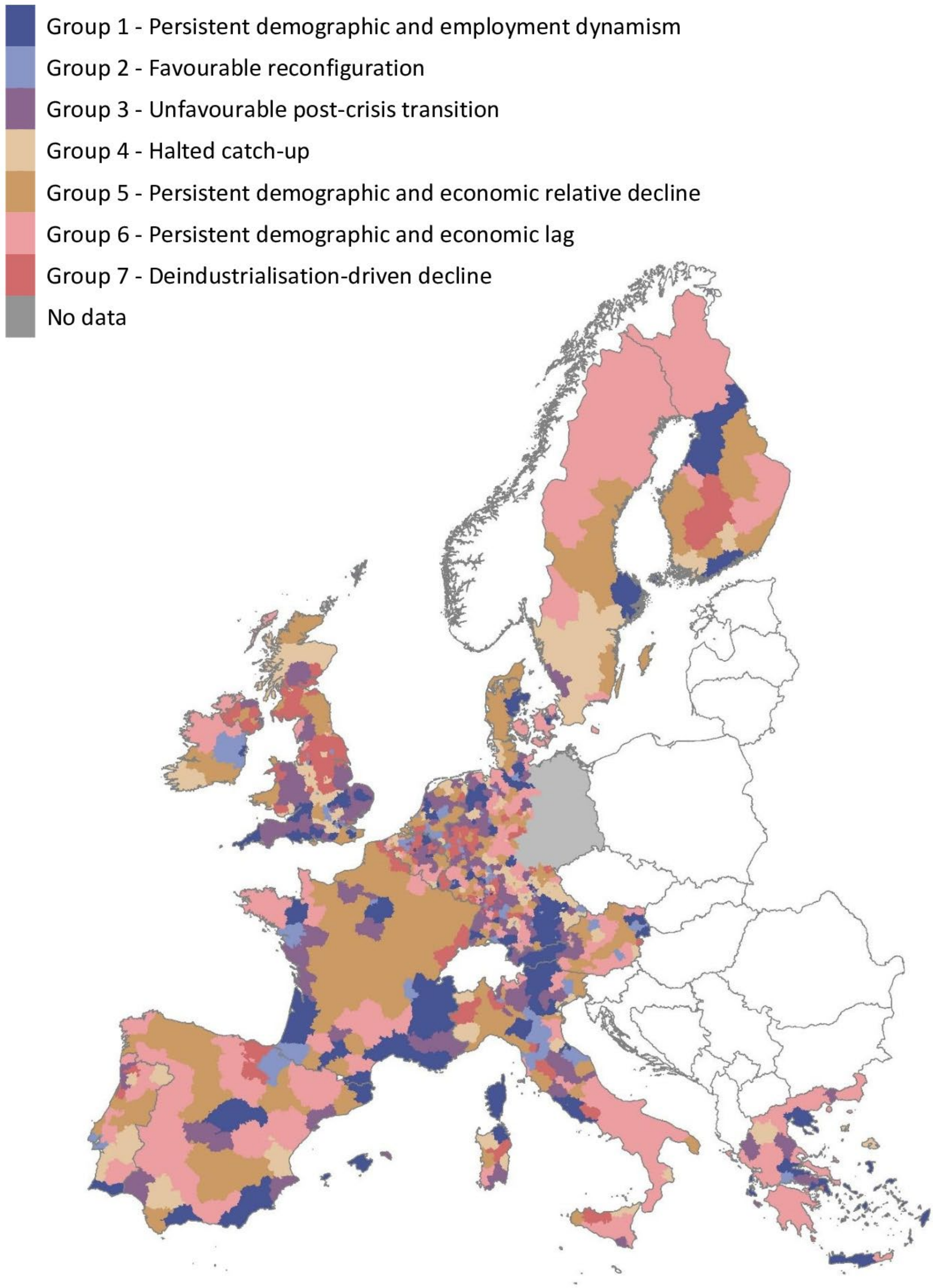


Figure 3: Typology of trajectories of NUTS3 regions across the EU15



Source: Authors' analysis based on ARDECO data. Boundaries are from EuroGeographics.

Group 1 – Persistent demographic and employment dynamism
147 regions

The majority of the regions in this group have experienced several 5-year periods of demographic and employment dynamism (cluster 1) since 1982, with more than 80% experiencing trajectories consisting of three or more cluster 1 intervals. The average GDP per head in this group of trajectories remains close to the average for the EU15 throughout the observation period, including during the various crises. This group therefore refers to favourable trajectories that are well anchored and have allowed a comfortable level of economic development to be maintained. All EU15 countries, with the exception of Luxembourg, have at least one region in this group, with a notable prevalence in Finland and Denmark (accounting for more than a third of the 2017 national population for both countries), as well as in Greece, Spain, France, Ireland and Sweden (accounting for more than a quarter of the 2017 national population).

Group 2 – Favourable reconfiguration
87 regions

The second group consists of less linear trajectories than in the first group, but still refers to overall favourable paths. Prior to the 2000s, we observe high shares of regions experiencing demographic and economic relative decline (cluster 4), as well as economic slowing and deindustrialisation (cluster 6). These dominant clusters of 5-year dynamics are then replaced by strongly growing shares of economic dynamism and financial and business growth (cluster 2), as well as demographic and employment dynamism (cluster 1) in recent years. This translates to trajectories of improvement, as regions have initially experienced restructuring phases before showing economic and/or demographic dynamism since the beginning of the new millennium. It is however important to note that the regions in this group started from a relatively better position compared to the other groups, for example with a higher average GDP per head in 1982. They also appear to be more geographically selective as they are absent from five countries[16], while accounting for more than 30% of the 2017 national population in Austria and Portugal.

Group 3 – Unfavourable post-crisis transition
140 regions

Having experienced initial spells of demographic and employment dynamism (cluster 1) and/or economic dynamism and financial and business growth (cluster 2), the regions in Group 3 have shifted to demographic and economic relative decline and/or lag (clusters 4 and 5). These two unfavourable clusters of 5-year dynamics became the most frequent after 2007, which may indicate a significant impact of the 2008 financial crisis. For regions in Group 3, the financial crisis seems to have interrupted positive trajectories that had until that point been similar to those in Group 1. This is particularly clear when looking at the average demographic dynamics in Group 3, which slowed significantly after the crisis, after having grown relatively rapidly. The economic structure of Group 3 has been one of the most stable. It is characterised by some deindustrialisation before the 2000s but still with 18% of total employment in this sector on average in 2017. This is the highest average of the seven groups of trajectories. This group of trajectories therefore refers to regions that have had difficulties maintaining their initial positive dynamics over the last decade or so. This type of trajectory appears to be quite common with no particular concentration in certain countries.

Group 4 – Halted catch-up
117 regions

The regions in Group 4 have followed similar paths to those in Group 3, but from a less favourable initial situation. The trajectories in Group 3 are then characterised by frequent spells of economic catch-up (cluster 3) before 2000, followed by fleeting economic dynamism and financial and business growth (cluster 2) for some regions, rapidly giving way to spells of demographic and economic relative decline and/or lag (clusters 4 and 5). Despite a similar end of period to Group 3, we still define Group 4 as representative of an interrupted catch-up rather than a failed one. On average, regions in Group 4 are characterized by a strong GDP growth which is not a reflection of population growth. As a result, the average GDP per head of Group 4 was the second lowest in 1982 before becoming the second highest in 2017. The economic structuring morphed in a similar way as for regions in Group 3, with deindustrialisation being more pronounced on average. The temporality of these trajectories suggests regions where incipient prosperity was slowed or halted after the financial crisis. Group 4 trajectories appear in twelve EU15 countries[17], with a particular prevalence in Sweden, where one third of the country's regions are included in Group 4, accounting for more than 40% of the 2017 national population.

Group 5 – Persistent demographic and economic relative decline
207 regions

This group of trajectories is the largest in terms of number of regions and the second largest in terms of the total 2017 population accounted for. It includes regions that have experienced several spells of demographic and economic relative decline (cluster 4), some demographic and economic lag (cluster 5), and little variety in terms of other clusters of 5-year dynamics. The result is a group of trajectories with the least heterogeneity of all the groups[18], describing a persistent demographic and economic relative decline. Regions in Group 5 started from a relatively high initial GDP per head level in 1982 and rarely experienced absolute decreases in GDP per head. In contrast, our results show negative average growth rates when measured against the national level, for both GDP per head and population and for all 5-year intervals. More than their economic structuring, which has evolved according to trends close to the average, these demographic and economic changes are the key aspects that define this group of trajectories. Group 5 therefore refers to regions that have experienced overall worse trajectories than the average development in their country.

Group 6 – Persistent demographic and economic lag
185 regions

Group 6 is characterised by a high share of demographic and economic lag over the entire period (cluster 5), with a noticeably growing share of demographic and economic relative decline (cluster 4). Regions in Group 6 are typified by the lowest average GDP over the entire period and the gap with other groups widens over time. Combined with frequent population loss in absolute and relative terms, average GDP per head remains the lowest of all groups from 1982 to 2017. Although both groups 5 and 6 are characterised by overall unfavourable trajectories, Group 6 includes regions that started from a comparatively worse initial situation and have struggled and/or failed to catch up, continuously lagging behind. Group 5, in contrast, is characterised by steep relative decline from a higher initial level of GDP per head. Another key aspect of Group 6, associated with this persistant lag, is the specific economic structure. Despite being the lowest of all groups, the average share of industry in total employment remained almost stable over the entire period. At the same time, the average share of other activities has decreased, with only the financial and business sector showing a slight expansion. This group of trajectories appears to be widespread in EU15 countries, with clear presence in Denmark, Italy and Greece and noticeable concentrations in northern Sweden and Finland, as well as southern Italy.

Group 7 – Deindustrialisation-driven decline
138 regions

Regions in Group 7 experienced initial spells of economic slowing and deindustrialisation (cluster 6) to an even greater extent than regions in Group 2, mainly followed by demographic and economic relative decline (cluster 4). The average share of industry in total employment fell from 38% in 1982 to 16% in 2017. In contrast to Group 2, this shift has been essentially directed towards activities other than the financial and business sector. We also identify some economic dynamism and financial and business growth (cluster 2) after 2000, with 60% of regions in Group 7 experiencing it at least one time. Compared to groups 5 and 6, the average GDP per head in Group 7 remains higher during the entire observation period, but is similarly drifting away from the national levels over time. This group of trajectories, then, refers to mainly unsuccessful reconfigurations, describing the other, rather unfavourable outcome for regions that started the observation period in a similar way to those in Group 2. Group 7 trajectories are observed in 12 countries, with a noticeable presence in the UK, where 54 regions out of 179 are included in Group 7, accounting for almost 30% of the 2017 national population.

5. Discussion

To contextualise our results, the following section places our different groups of trajectories into perspective in relation to the characteristics that they share or, on the contrary, that differentiate them. Group 1 (Persistent demographic and employment dynamism) consists of regions that have experienced trajectories predominantly made up of favourable phases, characterised by consistent absolute and relative growth in terms of population, GDP per head and employment. These regions are not therefore regarded as 'left behind' and not discussed in further detail. We first consider groups 2 (Favourable reconfiguration) and 7 (Deindustrialisation-driven decline) in terms of what their opposites reveal about deindustrialisation trajectories. At first sight, groups 3 (Unfavourable post-crisis transition) and 4 (Halted catch-up) can both be associated with the process of 'falling behind', but they relate to different timing of events. Finally, groups 5 (Persistent demographic and economic relative decline) and 6 (Persistent demographic and economic lag) depict relatively linear and unfavourable trajectories, with some relevant subtleties.

Groups 2 (Favourable reconfiguration) and 7 (Deindustrialisation-driven decline) illustrate how urbanised and industrialised regions have rebounded differently from seemingly similar phases of sectoral reorganisation (Hassink, 2010). Our results therefore confirm that the success of strategies to replace industrial activities by service sector activities is based at least in part on pre-existing conditions, from which not all regions benefited when these strategies were put in place.

Both groups, 2 and 7, do share certain similarities. For example, they are mostly urban areas and they saw substantial shrinkage of the industrial sector between 1982 and 2017. But whereas in Group 2 this was followed by periods of economic revival and re-orientation towards financial and business services, in Group 7 deindustrialisation appears to have resulted in sustained economic decline. With an initial path of decline that was favourably overturned, trajectories in Group 2 can be associated with the concept of positive path-creation through growth of services. However, this has been facilitated by favourable environments in these regions. Group 2 is charaterized by the highest average GDP per head among all other groups of trajectories since 1982 and is also the only group in which, on average, more than 50% of the group's population is working at any time stamp. This reveals underlying regional strengths in terms of economic prosperity and strong labour markets that have been maintained over time. The trajectories in Group 2 are therefore also representative of forms of positive path-dependency, insofar as they seem to be the result of both favourable pre-existing conditions and successful strategic adaptations. On the other hand, Group 7 illustrates the pattern most commonly identified as characteristic of the process of 'falling behind', through unsuccessful sectoral reconfiguration. Although the average GDP per capita for this group remained close to the overall average during the 1980s, it then moved away from it, as did the employment dynamics. The more general concepts of strong path-dependence and regional lock-in are consistent with the trajectories observed in Group 7, associated particularly with older industrial regions as illustrated by the Ruhr Area and the Basque Country being part of this group (Lengyel et al., 2022; Valdaliso, 2015).

By contrast, Groups 3 (Unfavourable post-crisis transition) and 4 (Halted catch-up) refer to non-linear trajectories of initially favourable dynamics followed by unfavourable ones. Although this may suggest 'falling behind' trajectories, further investigation conveys different outcomes. While the population dynamics and the sectoral changes appear quite similar between these groups, they experienced diverging pathways of economic performance relative to national levels. Group 3 had an average GDP per capita very close to national levels during the 1980s, before slowly diverging from them and increasingly so since the 2008 financial crisis. By contrast, Group 4 started with an average GDP per head lower than national levels, before quickly catching-up and staying at comparable levels since the

2000s. These dynamics suggest that, although regional trajectories appear to have been halted by recent economic slowdowns in both groups, the timing and the magnitude of such slowdowns were different. Regions in Group 3 seem to have had early phases of demographic and employment dynamism mainly as a result of an existing relative prosperity, before experiencing gradual economic de-coupling and peripheralisation (Kühn & Weck, 2013). Differently, Group 4 refer to regions that were successfully 'converging' and getting out of 'left-behindness', before being interrupted by the external shock of the financial crisis (Giannakis & Bruggeman, 2020; Sensier et al., 2016).

Finally, Group 5 (Persistent demographic and economic relative decline) and Group 6 (Persistent demographic and economic lag) both illustrate trajectories of continuous unfavourable change, suggesting that these regions have remained trapped in forms of 'left-behindness'. A key aspect involves population dynamics. Although regions in other groups have also experienced relative demographic decline[19], it is noticeably more steady and pronounced within groups 5 and 6, including for large urban areas such as Barcelona or Naples. This then suggests groups of trajectories characteristic of both rural depopulation and shrinking cities, without clear dominance of one process or the other in either group. Groups 5 and 6 do, however, differ in terms of GDP per capita, indicating different aspects of 'left-behindness'.

Group 5 has consistently shown a comparatively better economic situation than Group 6, but its average GDP per head has remained below the national level. This reflects low growth and a lack of regional attractiveness, which explains at least in part the unfavourable demographic dynamics. By way of example, the geographical configuration of the French regions in Group 5 clearly highlights the northeast to southeast diagonal, or the 'diagonale du vide' ('empty diagonal'). Long studied in the literature, this area includes regions that have suffered demographic and economic setbacks for several decades, and which today exhibit many of the attributes of 'left behind places'—that is, low population density, scarcity of employment and lack of services (Béteille, 1980; Bonnet et al., 2021; Oliveau & Doignon, 2016).

Of all groups of trajectories, Group 6 on the other hand is the one with the lowest average GDP per head over the entire period. Combined with successive spells of unfavourable changes, this suggests regions that were initially 'left behind' and have remained so in recent decades. This largely echoes the concept of 'lagging regions', areas characterised by chronic underperformance and failing to catch-up to national averages. As an illustration, several areas identified as 'lagging' by Pilati and Hunter in 2020 are clearly highlighted in this group of trajectories. The regions of southern Italy, southern Belgium, Spain and Portugal included in Group 6 are among the poorest and least growing and are therefore labelled as 'divergent' by the authors. Regions in Greece and the north-west of Ireland are also included in group 6 and are classified by the author as experiencing 'extremely low growth', another type of 'lagging region' they identify regardless of their income level (Pilati & Hunter, 2020).

6. Conclusion

Going beyond the observation between two points in time, our work addresses the empirics of 'left behind places' by identifying different possible transitions in and out of 'left-behindness' between 1982 and 2017 for EU15 NUTS3 regions. The seven groups of trajectories identified show variety in terms of the changes regions experienced over time, incorpororating both continuous and discontinuous sequences of 5-year dynamics. We draw out three broad categories of regional pathway. Groups of trajectories 1 and 2 refers to mainly positive situations that have been succesfully maintained over time or built up more recently. Groups 3 and 4 seem to characterise regions that have been interrupted in their growth and/or catching up, with Group 4 illustrating how fragile the recovery from 'left-behindness' may be. Groups 5, 6 and 7 refer to mainly unfavourable pathways that are variably rooted in pre-existing disadvantages or as a result of different wider crises. In this way, this paper provides "a more dynamic approach to grasp various sequences of pathways of growth and decline in particular types of regional contexts" (Blažek et al., 2020).

The research presented in this paper has some limitations. A first one concerns how the success or failure of regions is measured. Growth, whether demographic or economic, is still the most popular measure of regional performance and is often identified as absent or deficient in the context of 'left behind regions' (MacKinnon et al., 2022). Yet there may be tensions between the promotion of growth and the reduction of regional inequalities (Petrakos et al., 2011), while policies of 'rightsizing' or 'smart shrinkage' provide alternatives to growth (Béal, Fol, et al., 2019; Hummel, 2015; Küpper et al., 2018). Second, our approach required data covering several decades, limiting the number of dimensions that could be included to the indicators available in ARDECO. Third, our reliance on the NUTS3 scale makes is it diffiucult to identify sub-regional dynamics such as shrinking cities within larger regional aggregates.

Notwithstanding these limitations, this paper contributes to a better understanding of 'left behind places' and their dynamics in the EU15 by identifying different linear and non-linear regional trajectories. This allows us to address the often neglected temporal aspect of 'left-behindness', among a wide range of facets that make it a catch-all signifier. Moreover, our results highlight that, among seemingly similar regions in 1980, some have rebounded and evolved differently, suggesting that particular combinations of existing characteristics and practices over time have led to forms of regional resilience or even resurgence in some cases. More broadly, we argue that understanding past and on-going trajectories is essential for policy-makers and practitioners to properly comprehend the evolution of local and regional economies in order to inform future path development strategies (Hassink et al., 2019).

7. Endnotes

[1] In this document, the term is used to refer to the conditions that affect 'left behind places' and encompasses the diverse and changing definitions of this category.
[2] NUTS stands for Nomenclature of territorial units for statistics and is a hierarchical system for dividing up the economic territory of the EU. The database used in this analysis is the 2016 classification.
[3] For an illustration of this, see Supplementary material - Appendix 1.
[4] For more information on the observation interval length, see Supplementary material - Appendix 2.
[5] For more information on clustering 5-year 'dynamics' instead of 'states', see Supplementary material - Appendix 3.
[6] Clustering is performed with up to 1000 iterations and 500 random sets of starting points. The Hartigan-Wong algorithm is preferred and its results were found to be almost identical to those of Lloyd's implementation.
[7] The elbow method, the silhouette method, the gap statistic method were used.
[8] Although this may seem surprisingly heterogeneous, more than 800,000 unique sequences were possible with 7 clusters of changes over 7 observation intervals.
[9] For more information on Optimal Matching costs, see Supplementary material - Appendix 4.
[10] Using a combination of visual items such as the dendrogram with the optimal number of groups recommended by the WeightedCluster R package (v1.6-0, using 'as.clustrange').
[11] Translated from "*trajectoire dans son ensemble comme unité conceptuelle*".
[12] For more information on our input variables, see Supplementary material - Appendix 5.
[13] Excluded : 77 regions in East Germany for which there is no data between 1980 and 1990, all "Extra-Regio" territories (specific territories that cannot be attached to a certain region such as air-space, territorial waters, embassies, etc.), French overseas territories (Guadeloupe, Martinique, Guyane, La Réunion and Mayotte, respective NUTS3 codes are FRY10, FRY20, FRY30, FRY40 and FRY50) and 3 regions of the United Kingdom (Orkney Islands UKM65 for missing data, Camden & City of London UKI31 and Westminster UKI32 as they both are extreme outliers in terms of GDP, having substantial and unsatisfactory effects on clustering.
[14] Additional content on these clusters is available, including mean scores for each input variable and cluster (Supplementary material - Appendix 6), a table of cluster dominance per period (Supplementary material - Appendix 7), a detailed table of trends for each input variable and cluster (Supplementary material - Appendix 8) and extended cluster descriptions (Supplementary material - Appendix 9).
[15] The medoid is the region with the smallest weighted sum of distances to other observations in a group (Studer, 2013). The medoid trajectory is therefore the most 'central' of each group of trajectories and serves as the most representative example possible for the whole group.
[16] Denmark, Greece, Finland, Luxembourg and Sweden.
[17] Absent from Denmark, France and Luxembourg.
[18] Using intra-class distances and transversal entropies.
[19] Measures relative to the national growth rate are preferred to highlight any regional lack of attractiveness within the same country and account for country-level differences in population dynamics.

8. References

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Supplementary information

Appendix 1: Testing short-term inertia in terms of regional population change.

We would like to illustrate how measuring regional change between two distant points in time can obscure more complex trajectories of successive short-term changes. We therefore investigate the degree of discontinuity over time in terms of demographic change of a region and that the one observed between 1980 and 1985, for example, does not necessarily come with a high inertia for later periods. We test this with a correlation analysis for the population change rate between 5-year periods, the results of which are presented in Appendix 1 – Table 1. It can be seen that, although the change observed over a 5-year period is often similar to that observed over the following five years, the coefficients do not exceed 0.73 and are higher for the most recent periods. This shows that for the same area the demographic decline or growth can be significantly different from one 5-year period to another, and this is particularly evident between 1980 and 1990.

Appendix 1 – Table 1: Population change over 5-year periods in the EU15 – Spearman correlation coefficients

Periods	1980 to 1985	1985 to 1990	1990 to 1995	1995 to 2000	2000 to 2005	2005 to 2010	2010 to 2015
1980 to 1985	*1,00*	0,15	0,45	0,52	0,46	0,35	0,23
1985 to 1990	0,15	*1,00*	0,45	0,36	0,20	-0,09	0,02
1990 to 1995	0,45	0,45	*1,00*	0,66	0,49	0,28	0,28
1995 to 2000	0,52	0,36	0,66	*1,00*	0,66	0,31	0,29
2000 to 2005	0,46	0,20	0,49	0,66	*1,00*	0,69	0,49
2005 to 2010	0,35	-0,09	0,28	0,31	0,69	*1,00*	0,73
2010 to 2015	0,23	0,02	0,28	0,29	0,49	0,73	*1,00*

Source: Authors' analysis based on ARDECO data.

Appendix 2: Observation interval length

Within our available data, which range from 1980 to 2017, we had to decide on the length of the short-term intervals. The objective is to calculate various indicators between these 'time stamps' in order to characterise the regions' trajectories during this short period. The choice of the observation interval thus determines the frequency with which each region will be able to change clusters once they have been identified by the k-means clustering, and therefore the level of temporal detail with which the sequences will be defined.

The ARDECO data are available annually and therefore allow the construction of detailed sequences, especially compared to what can be observed in the literature on neighbourhood trajectories where the intervals are often ten years (Delmelle, 2016; Patias et al., 2021). However, having this possibility to work annually does not necessarily imply that it is the most appropriate, especially given the other parameters of our framework.

Going back to our research objective, the changes we are seeking to capture to reflect forms of 'left-behindness' are usually observed over several years or decades. This is particularly true given the NUTS3 geography used, with little chance that major transformations of regions will be contained between two years and vanish outside this window. After testing, annual changes are often rather small and different from one year to the next, resulting in very erratic sequences. Ultimately, the groups of trajectories constructed retain significant residual intra-class heterogeneity, making the interpretation of the typology complicated and hazardous. Although we may lose some accuracy in identifying the exact timing of possible 'breakpoints' in the trajectories of the regions, the use of longer observation intervals does not seem to be a major drawback in understanding the general trajectories experienced by these regions.

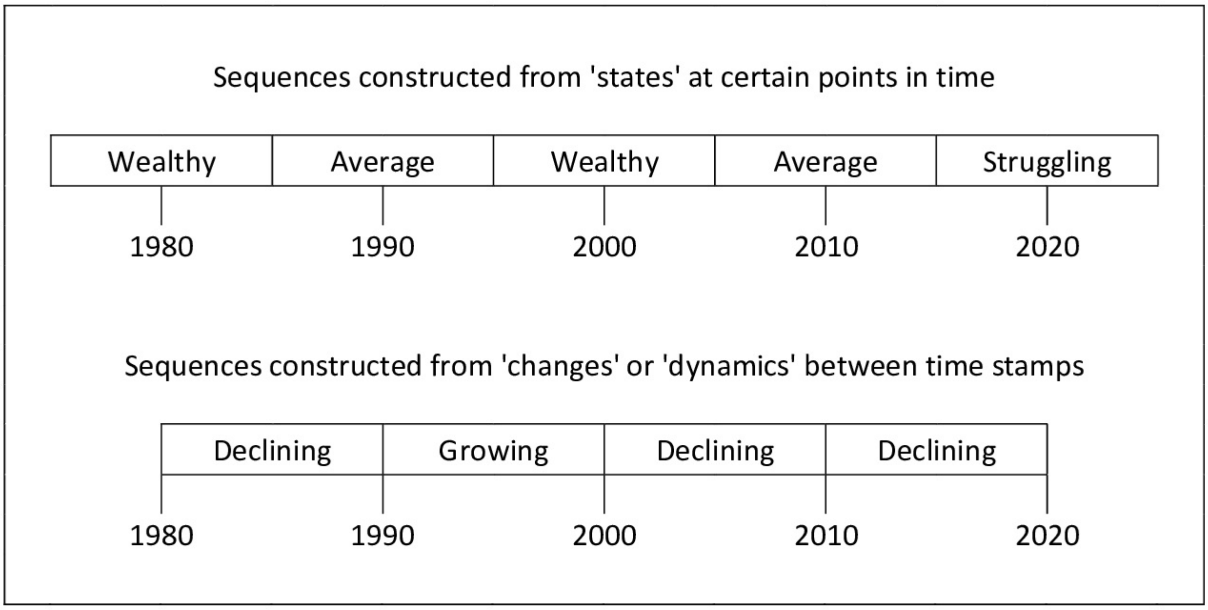
These elements have led us to formulate a methodological compromise specific to our study, which will be to work on the basis of 5-year observation intervals. The use of the most recent data is preferred, which leads us to choose seven intervals and eight time stamps from 1982 to 2017.

Appendix 3: Clustering 5-year 'dynamics' or changes instead of 'states'

Step 1 of the protocol is dedicated to identify k groups of statistical units for which the values of the input variables are close, thus creating a typology of possible 'states'. One of these states is then assigned to each statistical unit at each observation time, the succession of these states constituting the sequences to be studied. This normally involves the selection of static input variables that measure values at different points in time.

However, as our focus is more on the study of the process than on the structure (Sackmann & Wingens, 2003), we seek to highlight the dynamic dimension of 'left-behindness' for the NUTS3 regions of the EU15. This is reflected in the choice of dynamic indicators as input variables, measuring changes between periods. Rather than clusters of 'states', the initial k-means clustering is then used to find clusters of 'changes', the succession of which constitute the trajectories of interest for the subsequent steps of the analysis. Using a fictitious example, we illustrate the two types of approach in Appendix 3 - Figure 1.

Appendix 3 – Figure 1: Sequence construction processes



Source: Developed by authors.

As an additional note about the initial k-means clustering, it is conducted simultaneously on all 7,147 statistical units, which are all possible NUTS and intervals combinations (1,021 regions x 7 intervals). The use of such pooled dataset can be found in neighbourhood related trajectories studies (Delmelle, 2016), and ensures "temporal consistency and comparability of cluster membership in the resulting partitioning solution." (Patias et al., 2020).

Appendix 4: Setting Optimal Matching costs

Below we detail our choices regarding our OM costs. First are substitution costs, which determine how 'easy' it may be to move from one ‘state’, or in our case ‘cluster’, to another. It is possible to use different substitution costs for different transitions when justified by certain hypotheses, e.g. when studying transition between hierarchical ‘states’. For example, regarding employment trajectories, one could say that going from unemployed to part-time employment is ‘easier’ and then less ‘costly’ while measuring sequence dissimilarity, compared to going from unemployed to full-time employment. In our case the different ‘states’ are clusters of 5-year dynamics and are determined by the data. This does not imply any assumption of hierarchisation between clusters and would suggest to set constant substitution costs, moving from any cluster to any other having the same cost. Nevertheless, we choose a third option which is to work with data-driven costs. Although no clear hierarchy can be highlighted, we have shown that there could be a form of inertia in some of the changes we investigate. Without trying to precisely characterise this inertia, we take it into account by deriving substitution costs from transition rates (Rohwer & Pötter, 2005). The resulting cost matrix does not present any major inconsistencies and has proven to be just as relevant as the use of constant costs in terms of results, while being conceptually grounded. The second cost to be determined is the insertion/deletion or indel cost, the value of which influences the importance given to one or more aspects of the trajectories, namely sequencing, timing or duration. In our case, this cost is set at half the maximum substitution cost, reflecting the fact that we are indifferently interested in the three aspects. Although no combination of OM cost is foolproof (Stovel et al., 1996), comparative tests with other costs have confirmed the relevance of our choices for measuring dissimilarity between sequences.

Appendix 5: Designing input variables

For each indicator, four possible variants were available in the ARDECO database. They result from the different combinations between (1) having measurements at a given time ("point-in-time") or dynamically (growth rate) and (2) having measurements in absolute or relative values at national level.

Regarding the first pair of options, we favour dynamic measures, following the idea of a study focused on processes related to 'left-behindness', as developed previously. In terms of input variables, this translates into different ways of measuring changes between time stamps, depending on the input variables. Regarding demographic change, GDP per head and total employment, we calculate the growth rate between time stamps. This measure remains sensitive to episodic variations as it only takes into account the values at the beginning and end of the observation interval. However, smoothing out episodic variations did not appear necessary given the geographical scale and the sizable temporal inertia of population, GDP per head and total employment. On the other hand, sectoral change is measured by subtracting each sectors' employment share at the start of the observation interval from its share at the end of it[1]. Building on recent research focused on economic restructuring in the EU15 (Velthuis et al., 2022), we favour this measure over the growth rate which remains sensitive to the initial size of the sector. As such, using any growth rate indicator to measure sectoral change can result in a high growth rate even with a relatively small absolute employment increase if the initial size of the sector is rather small in the region. Conversely, a relatively large increase in employment in absolute terms may translate into a small growth rate if the size of the sector is larger[2]. Therefore, we consider that the change in a sector's share of total employment is a better way of characterising the overall structure of employment changes over time. This variable is calculated for sectors for which data are available, and which are of interest in terms of 'left-behindness', i.e., the industrial sector, the financial and business services sector, as well as for a third group gathering all other jobs in the region[3]. In addition to these dynamic measures, we also use a point-in-time one regarding the GDP per head. The rationale behind using both measures rely on the fact that the region's GDP level is also an accurate information in terms of 'left-

[1] For example, if in 1992 10% of the region's workforce was employed in the financial and business service sector but in 1997 15% of the region's workforce was employed in this sector, we are measuring an increase of 5 percentage-points.

[2] For example, if the number of workers in the financial and business sector increases from 1,000 to 1,500 in a region with over 30,000 workers, the sectoral change will remain fairly inconsequential in the grand scheme of things, even if the growth rate measured is quite high.

[3] As no data were available for other sectors, this indicator is introduced to control for changes in a broad category regarding the rest of the region's employment. It is obtained by subtracting the number of people working in the industrial sector and in financial and business services from total employment. In addition, this input variable has proven to be useful to the overall convergence and fit of the analysis.

behindness', especially when considering the GDP change. Regions which do not experience much growth but are already at a relatively high level of GDP per head appears to be much less 'left behind' than regions which fail to grow from a very low level of GDP per head. As a result, we include this point-in-time measure as one and only exception to our dynamic set of input variables[4].

Regarding the second choice to be discussed between an absolute or relative measure, we have different reasoning depending on the variables. A measure relative to the national level is preferred for demographic change, GDP and total employment[5]. Although an absolute measure can be used to analyse the change of these indicators over time and space (Dijkstra et al., 2020), a relative measure allows to neutralise the differences between countries. Considering that our goal is to identify 'left behind' trajectories, it seems relevant to take into account the country effect and evaluate the extent to which the region has developed differently from the country to which it belongs. This reasoning is useful, for example, to show the limits of a "continued top-down nature of measuring EU performance" based on GDP, around the concepts of convergence and lagging regions (Pilati & Hunter, 2020). As an example, in our study, a measure of population dynamics relative to the national level makes it possible to reconsider the case of territories that have gained population over the observation period in absolute terms, but whose demographic growth is slower than the national average. This then can show a sign of a certain lack of local attractiveness, despite a gross demographic dynamic that could appear positive in relation to other EU15 regions outside this country. Regarding the input variables related to sectoral change, we use measures that are not relative to the national level. These indicators are used to characterise forms of 'left-behindness' through the regional employment opportunities that individuals and households face, rather than measures at the aggregate level, for which the other (relative) variables are intended. As a result, although regional sectoral change may not have the same implications depending on the national sectoral structure, the choice of a relative measure has not proved decisive[6].

Our choices regarding input variables were thus guided both by conceptualisation and literature, but also by technical limitations. In this respect, we can point out that the number

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[4] Although the same reasoning could be applied to other input variables, we believe that it is particularly true in the case of GDP per head. Furthermore, we also want to limit as much as possible the addition of point-in-time measures in order to preserve the coherence of our conceptualisation centred on the dynamics of 'left-behindness'.

[5] Measures relative to the national level are obtained by subtracting from the regional growth rate that of the country in the case of growth rates and by dividing the regional point-in-time value by that of the country in the case of point-in-time indicator.

[6] In addition to conceptual reasons, tests based on relative measurements have not shown them to be more relevant.

of input variables included for each dimension represents its respective weight in the k-means clustering[7], and by extension in the resulting understanding of 'left-behindness'. Although we would have liked to use a more multi-dimensional approach to the concept, data availability leads us to combine 2 dimensions with a comparatively high weight for the economic component. We believe that this relative imbalance does not pose a fundamental conceptual problem, given the preponderance of economic dynamics in our current understanding of 'left-behindness'.

[7] Technically, one could weight the variables in the statistical analysis to compensate for and add more input variables, but this implies (1) different technical complications and (2) justifying the weights chosen.

Appendix 6: Clusters with their mean score for each input variable.

Appendix 6 – Table 1: Clusters with their mean score for each input variable.

	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**	**Cluster 7**
Population growth *Relative to national*	0,0310	0,0008	-0,0056	-0,0146	-0,0138	-0,0047	-0,0041
GDP per head *Relative to national*	0,9849	0,9969	0,8195	0,8916	0,8070	1,0049	0,9770
GDP per head growth *Relative to national*	-0,0200	0,0061	0,1462	-0,0256	-0,0078	-0,0235	0,0024
Total employment growth *Relative to national*	0,0386	0,0157	0,0442	-0,0310	-0,0296	-0,0096	-0,0217
Change in the industrial sector	-1,0333	-1,5945	-0,9841	-1,9113	0,4878	-5,5213	-0,6593
Change in the Fin & Bus sector	0,5747	2,9698	0,6394	0,7262	0,7293	1,1861	-3,4958
Change in other activities	0,4586	-1,3774	0,3447	1,1876	-1,2168	4,3352	4,1551

Source: Authors' analysis based on ARDECO data.

Appendix 7: Share of each observation interval by cluster.

Appendix 7 – Table 1: Share of each observation interval by clusters.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
1982 to 1987	6%	19%	19%	8%	18%	12%	13%
1987 to 1992	10%	25%	22%	7%	15%	11%	12%
1992 to 1997	18%	25%	15%	7%	16%	14%	12%
1997 to 2002	22%	16%	16%	19%	12%	12%	14%
2002 to 2007	7%	10%	8%	31%	12%	13%	16%
2007 to 2012	25%	3%	13%	13%	14%	15%	18%
2012 to 2017	12%	2%	5%	15%	14%	23%	15%

Source: Authors' analysis based on ARDECO data.

Appendix 8: Clusters of 5-year dynamics (detailed trends).

Appendix 8 – Table 1: Clusters of 5-year dynamics (detailed trends)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Short name	Demographic and employment dynamism	Economic dynamism and Fin & Bus growth	Economically catching up	Demographic and economic relative decline	Demographically and economically lagging	Economic slowing and deindustrialisation	Employment slowing and Fin & Bus decline
Demography	Strong relative growth	Average relative change	Relative decline	Strong relative decline	Strong relative decline	Relative decline	Relative decline
GDP	High initial level	High initial level	Low initial level	Average initial level	Low initial level	High initial level	High initial level
	Strong relative decline	Relative growth	Strong relative growth	Strong relative decline	Relative decline	Strong relative decline	Average relative change
Employment	Strong relative growth	Relative growth	Strong relative growth	Strong relative decline	Strong relative decline	Relative decline	Strong relative decline
Economic structuring	Deindustrialisation	Deindustrialisation	Deindustrialisation	Deindustrialisation	Dynamic or resilient industry	High deindustrialisation	Low deindustrialisation
	Fin & Bus growth	Fin & Bus strong growth	Fin & Bus growth	Fin & Bus growth	Fin & Bus growth	Fin & Bus growth	Fin & Bus strong decline
	Other activities growth	Other activities decline	Other activities growth	Other activities growth	Other activities decline	Other activities strong growth	Other activities strong growth
Temporality	All periods, slightly more old ones	Concentration after 1997	Concentration before 2002	All periods, slightly more recent ones	All periods, more between 2012 and 2017	High concentration before 2007	1987 to 2002 and 2007 to 2017

Source: Authors' analysis based on ARDECO data.

Appendix 9: Detailed clusters descriptions.

Cluster 1 – Demographic and employment dynamism
1415 region-period pairs

Cluster 1 includes significantly more region-period pairs than the two other 'overall positive 5-year dynamics' clusters, i.e., cluster 2 and 3[14]. This cluster is mainly characterised by positive dynamics in terms of population and employment. Though we see relative decline in GDP per head in much of this cluster, the vast majority of region-period pairs actually experienced growth in their aggregate GDP, both in absolute terms and relative to the national level. The relative decline in GDP per head is therefore essentially a consequence of population growth. This, together with a relatively high initial level of GDP per head, depicts a cluster of favourable 5-year dynamics, led by demographic and employment dynamism. The shifts in terms of sectorisation of employment do not seem to be very different from the average for the EU15 as a whole. This cluster is widespread in space and time, without any particular pattern.

Cluster 2 – Economic dynamism and finance & business growth
765 region-period pairs

Cluster 2 is characterised by relatively high levels of GDP per head at the beginning of the observation interval, associated with a positive change in the following years. The labour market also appears to be dynamic, with the share of the financial and business sector tending to increase significantly over the observation interval, replacing other activities. Most of the regions included in this cluster appear in a particular decade, generally around the year 2000, as in Austria, West Germany, Denmark or the UK. The combination of these elements and the temporality of the cluster make it characteristic of relatively wealthy regions where the development of activities in the financial and business sector seems to have been beneficial.

Cluster 3 – Economically catching up
750 region-period pairs

On average, the region-period pairs in cluster 3 experienced positive GDP per head and employment changes, similarly to cluster 2, but from a much lower initial level of GDP per head, indicative of "economic catch up". As for cluster 1, the sectoral changes in this cluster are broadly in line with the average for all EU15 regions. The temporal concentration is clear before 2000 and is also observed at the country level. More than half of the Finnish and Swedish regions belong to this cluster for the period 1982-1987 and more than half of the Portuguese regions during the following observation interval.

Cluster 4 – Demographic and economic relative decline
1831 region-period pairs

The fourth cluster is the first of the ‘overall unfavourable dynamics’ clusters identified and constitutes the largest share of all the region-period pairs. On average, the regions in cluster 4 experienced the most unfavourable dynamics for all measures related to the national level. The average trends observed here are similar to those in cluster 5 but with a higher initial relative level of GDP per head. Although the relative decline of this indicator appears stronger in cluster 4 than in cluster 5, the average level of GDP per head at the end of the observation interval remains higher in this fourth cluster. In general, this cluster thus refers to clear decline, without specificity in terms of economic structuring or temporality.

Cluster 5 – Demographically and economically lagging
1495 region-period pairs

Also accounting for a large share of all the region-period pairs, the dynamics in this cluster resemble those of cluster 4 with negative changes regarding population, GDP per head and employment. One key difference is that the relative GDP per head at the beginning of the period is lower for cluster 5. This cluster then refers to a category of territories that seems to be demographically and economically lagging behind national levels. The industrial sector either shrinks more slowly than in other clusters or even increases. Upon further investigation, it is less often a case of a proper 'industrialisation' of activity than of a resilient industrial sector in an environment where total employment is decreasing. In terms of temporality, cluster 5 appears during all observation intervals, with a clear over-representation during the 2012-2017 interval. Apart from Sweden and Luxembourg, at least 1 region out of 5 is assigned to this cluster for this period in all countries, with a maximum of 84% of Portuguese regions included.

Cluster 6 – Economic slowing and deindustrialisation
675 region-period pairs

Cluster 6 is associated with economic relative decline and high deindustrialisation. Despite being common over the period in the EU15 and visible in other clusters, deindustrialisation appears to be particularly intense in cluster 6. Among the 675 region-period pairs in this cluster, not a single one has seen a reduction in the share of employment accounted for by the industrial sector of less than 3 percentage points over 5 years. In comparison, this is the case for less than one in ten region-period pairs belonging to other clusters. In terms of temporality, the prevalence of this cluster during the 1980s and 1990s is indeed found in all countries, albeit with some specificities. The French and Spanish regions included in this cluster are essentially in the 1980s, whereas in Belgium, West Germany and the Netherlands it is more likely to be in the 1990s.

Cluster 7 – Employment slowing and fin & bus decline
216 region-period pairs

Finally, cluster 7 is a good example of how temporality plays a role in our use of the k-means clustering and, more generally in understanding 'left-behindness'. On average, the region-period pairs in cluster 7 experienced employment relative decline associated with a strong decline in the employment share of the financial and business sector, from a comfortable GDP per head initial level. The cluster is also characterised by a specific temporality, being mostly present between 1987 and 2002, as well as between 2007 and 2017. These elements thus suggest changes in these regions that may be linked to wider crises, notably the recession of the late 1990s and the financial crisis of 2008. While only 216 region-period pairs are part of this cluster, 11 countries are represented. The phenomenon seems particularly pronounced in the Netherlands, with 40% of the country's NUTS3 regions included in the cluster for the period 1997 - 2002 and 30% for the period 2007 - 2012.