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Citation for final published version:

Webber, Don J., Healy, Adrian and Bristow, Gillian 2018. Regional growth paths and resilience: A European analysis. *Economic Geography* 94 (4) , pp. 355-375.  
10.1080/00130095.2017.1419057

Publishers page: <http://dx.doi.org/10.1080/00130095.2017.1419057>

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# Regional growth paths and resilience: a European analysis

**In: Economic Geography**

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**Acknowledgements:** The authors thank delegates for helpful comments at RSAI:BIS 2014 and RSA 2015 annual conferences.

## **Abstract**

Research highlighting the differential resilience of economies to shocks opens up the possibility that long-run growth paths are associated with how regions cope with and recover from such shocks. To date, however, there has been limited exploration into whether long-run evolutionary growth paths or trajectories influence regional economic resilience, and what types of trajectory might be more associated with resilience. This paper explores the connections between regional economic resilience and regional and national growth trajectories by utilizing a novel set of methods to group regions according to the similarity of their growth paths, identifying the relative importance of national growth for regional growth, and categorizing regions according to their resilience to the 2007-2008 economic crisis. The results suggest that regions have empirically identifiable long-run and path-dependent development trajectories that are significantly associated with industrial employment shares and observed resilience outcomes. Critically, however, these regional growth paths are significantly shaped by national trajectories. Furthermore, regions with greater employment shares in sectors that are less susceptible to demand fluctuations are likely to experience more stable growth rates and be more resilient to economic downturns. This has implications for understanding the importance of evolutionary trends and specifically the role of national contexts and industrial legacies in shaping regional resilience.

**Key words:** Resilience; Trajectories; Evolutionary Economic Geography; GVA.

**JEL classification numbers:** R11; R58; R23

## 1. Introduction

The economic crisis of 2007-2008 heralded the most severe economic downturn in the history of the European Union. Studies of the socio-spatial trajectories around the crisis have identified a complex web of origins and reactions, and highlighted its uneven regional and local effects (Hadjimichalis and Hudson, 2014; Sensier *et al.*, 2016). The differential responses of regions to the crisis have drawn attention to the relationship between longer-term trends in a region and its ability to weather such shocks and exhibit resilience (Hassink, 2010; Scott, 2013). In particular, evolutionary economic geographers have asserted that a region's resistance to and recovery from shocks may be a consequence of its previous growth path (Martin and Sunley, 2015).

Conceptual and empirical understanding of the nature of the relationship between long-term regional economic trajectories and resilience to economic shocks remains limited however. Existing analyses have made some attempt to capture the influence of 'initial conditions' of regional economies when confronted with crisis in shaping subsequent shock impacts (e.g. Davies, 2011). In a study of the impact of the 2007-2008 financial crisis and subsequent recession on several European regions, Davies *et al.* (2010) found that in addition to various other factors, regions that were weaker or suffering relatively poor economic performance prior to the crisis were more likely to experience more severe effects as a result of the crisis. Such regions were posited as being more likely to suffer further damaging long-term effects from the crisis because the loss of even a relatively small number of jobs and firms in such regions, leads to a much wider reduction in demand for goods and services from local firms. However, these analyses are partial and tend to focus on starting points or levels of growth, and do not fully capture the role of evolutionary regional economic trajectories or paths in the run-up to the crisis. As such, they leave considerable questions regarding whether

both long-run regional trajectories *before* the crisis influenced and shaped how resilient regions ultimately were *to* it, and what kinds of trajectory might be more associated with resilience.

These are undoubtedly challenging questions to address. There has long been interest amongst economists and economic geographers in the theorizing and empirical analysis of regional economic trajectories or long-term trends in regional economic productivity. This reflects the wider interest and asserted necessity of studying change in regional development (as opposed to simply growth) trajectories in longer historical contexts (Martinelli *et al.*, 2013). However, there is still much to be discerned about how long-run regional trajectories are configured, and indeed what commonalities may exist between them to enable particular ‘types’ of trajectory to be defined (e.g. Dijkstra and Poelman, 2011). Evolutionary economic geography (EEG) is beginning to offer some insights however. EEG focuses on the processes that transform the economic landscape over time including the spatial organization of production, distribution and consumption (Boschma and Martin, 2007). In particular, it asserts that regional trajectories are complex and contingent and shaped by both localized and spatially-bounded elements as well as by the ‘memory’ of each region’s particular historical industrial development structure (Maskell and Malmberg, 2007). This is evidenced by continued regional disparities within national economies (Rodriguez-Pose and Crescenzi, 2008), coupled with considerable heterogeneity in regional business cycles which are not always synchronized with national ones (Mastromarco and Woitek, 2007; Owyang *et al.*, 2009). Similarly, EEG suggests that specific regional industrial structures may have an important role to play in shaping both long-run evolutionary trajectories and resilience to shocks (Boschma, 2015). However, the precise significance and nature of this is subject to some debate with Martin *et al.* (2016) observing that regional responses to shocks are not always consistently linked to regional industrial structures either geographically or

temporally. Furthermore, the evolutionary conception of regional resilience is still developing and subject to much scholarly debate (Bristow and Healy, 2014; Boschma, 2015; Martin and Sunley, 2015). What is clear is that evolutionary thinking on resilience defines it as a complex, multi-dimensional concept which has a temporal dimension. This makes it challenging to operationalize, particularly in the case of comparative regional analysis where shocks and stresses may affect regions at different times and in different orders of magnitude (Foster, 2012; Martin, 2012).

The purpose of this paper is to explore these challenges and to seek to understand the extent to which certain identifiable regional economic trajectories are more likely to be associated with greater regional economic resilience. Critical to this resilience debate are two substantive issues: first the extent to which regional economic trajectories are distinct from national ones, and second the role of industrial structure and particular sectors in shaping trajectories which facilitate regional resilience. We contribute to evolutionary approaches to resilience by developing an innovative analysis of the relationship between observed long-run regional trajectories around a crisis and a new method of measuring regional economic resilience outcomes nested within countries across Europe. We group individual regions according to the similarity of their trajectories, identify the relative importance of national growth trajectories for regional ones and examine whether the evolution of different sectoral structures plays a role in creating trajectories associated with favorable resilience outcomes.

The paper is structured as follows. The next section explores evolutionary economic geography propositions regarding both long-run regional economic trajectories and conceptions of resilience, as well as the relationships between them. Section three details a novel methodological approach for grouping regions according to the similarity of their growth paths or trajectories. It also details methods that we use to assess the relative importance of the national level for regional growth paths. In section four we present our

analysis of the relationship between resilient outcomes and regional trajectories and consider the role of sectoral effects on observed patterns. In the concluding sections we reflect upon the implications of these results for our understanding of the relationship between long-run patterns of regional development and regional economic resilience.

## **2. Regional economic trajectories, evolution and resilience**

Recent scholarly contributions in EEG have made significant progress in understanding how regional economic resilience may be conceptualized. An evolutionary perspective conceives regional economic resilience as a multi-dimensional, adaptive concept embracing resistance (the degree of sensitivity or depth of reaction to the shock); recovery (the speed and degree of recovery from the shock); re-orientation (the extent to which the region adapts and re-orientates in response to the shock); and renewal (the degree to which the region resumes its pre-shock growth path) (Martin, 2012). This notion of resilience as a multi-faceted process has been further developed by Martin and Sunley (2015) who assert that resilience can be viewed as comprising four sequential (and recursive) steps: the risk (or vulnerability) of a region's firms, industries, workers and institutions to shocks; the resistance of those entities to the impact of shocks; the ability of those entities in the region to undergo the adaptations and adjustments necessary to resume core functions and performances; and finally, the degree and nature of recoverability from the shock. As such, there is an emerging consensus that regional economic resilience may be defined as the capacity of a regional or local economy to withstand, recover from and reorganize in the face of market, competitive and environmental shocks to its developmental growth path (Cooke, 2012; Bristow and Healy, 2014; Boschma, 2015; Martin and Sunley, 2015).

Operationalizing the concept of resilience is by no means an easy task however. Sensier *et al.* (2016) confront this problem in their comprehensive cross-comparative analysis of the effects of the 2007-2008 global financial crisis on European regions. They develop an approach which measures and defines resilience as the ability of an economy to maintain existing levels of economic activity in the face of an economic shock, or to recover to the pre-shock peak within a given time period. This has the advantage of focusing analysis on short-term, post-shock outcomes in regional economic performance rather than longer-term adaptive capacities and processes (Bristow and Healy, 2014), thus capturing the immediate resistance and recoverability of regions to shock. This approach also adapts available methods for dating regional business cycles to capture differences in both the timing of when the shock hit regions, and the amplitude and duration of both the downturns experienced and subsequent recoveries. Once the business cycle has been constructed for each individual territorial unit, the amount of employment lost between the peak and trough turning points of the output cycle is calculated. This allows resilience to be gauged by measuring how much employment is lost over downturns, and to calculate the time to recovery. This method also follows Martin (2012) in that it measures the absolute resilience of the economy to an economic shock, rather than its resilience relative to other economies.

Using this approach, an economy is considered to be resilient if it has recovered to its peak employment levels within three years of experiencing an economic downturn (Sensier *et al.*, 2016). Each economy is therefore judged to be either: *Resistant* (i.e. it did not experience a downturn following the economic shock); *Recovered* (it experienced a downturn in economic activity but recovered to pre-shock peak levels in three years); *Not-Recovered: Upturn* (it registered an upturn in activity levels but had not recovered to its pre-shock peak in three years); and *Not Recovered: Downturn* (it was still to record an upturn in activity after three years).



## *Long-term regional economic trajectories and resilience*

The developing evolutionary thinking on regional economic resilience has spawned a growing scholarly literature seeking to understand why some regions are more resilient to shocks than others. Regional economic resilience, as conceptualized, is understood to be dependent upon the nature, depth and duration of the shock, as well as on the prior growth path of a region, and on the various determinants of that growth path (including regional economic structures, resources, capabilities and competences), together with any supportive measures undertaken by local or national institutions (Boschma and Martin, 2010; Martin *et al.*, 2016). Whilst it is asserted that ‘long-run trends and shifts in regional economies, in both their industrial structures and locally specific conditions and factors affecting economic performance across sectors, are key influences on the evolving geographies of resistance to and recovery from recessions’ (Martin *et al.*, 2016; p. 581), the importance and nature of these ‘influences’ remain somewhat opaque.

Martin and Sunley (2015) point to some of the conceptual challenges in investigating these interactions, notably in the dialectical and cumulative nature of regional growth, which purports that a region’s recovery from shocks may be both a consequence of its previous growth path and a causal determinant of its future trajectory. Recessionary shocks may, for example, have permanent or hysteretic effects on a region’s growth trajectory. Thus, a region that experiences a particularly severe contraction in its economy after a recessionary shock may not return to its previous trajectory, but emerge on a lower or inferior growth path (Martin, 2012; Isaksen, 2015). This may, in turn, act as a key influence on its ability to resist or recover from future shocks. As such, resilience and a region’s ‘cyclical dynamics are embedded within - are both shaped by and help shape - long-term regional development

paths' (Martin *et al.*, 2016, p. 581). Separating trend and cycle may therefore potentially be misleading.

A further set of questions surrounds the possibility and utility of discerning general patterns or commonalities within long-run regional trajectories. With the development of endogenous growth theory in the 1980s came the notion of club convergence, which articulated the hypothesis that only countries (and regions within them) with similar structural characteristics and initial conditions would experience convergence or similarity in their growth patterns. Martin and Sunley (1998) cite a number of studies (notably Quah, 1993; Armstrong, 1995; and Canova and Marcet, 1995) which provide clear evidence of geographic clustering of regional growth rates in Europe and the US. As such, they observe that 'fast growth regions tend to be spatially clustered with other fast-growth regions, and similarly, slow-growth regions tend to be geographically grouped in close proximity' (Martin and Sunley, 1998, p. 206).

These studies are problematic however inasmuch as they assume that regions are converging to some common equilibrium state, when in reality, different regions may converge to different long-term relative income levels or growth paths in accordance with persistent local differences in structural characteristics. Indeed, proponents of EEG assert that regional economies are likely to exhibit highly variable and non-equilibrium dynamics and thus 'evolve and move along open-ended developmental trajectories with an unknown endpoint' (Hudson, 2010, p. 13). Furthermore, existing approaches to the identification of similar regional trajectories fail to take into account how different regions relate to one another and their national context, and thus how the growth trajectory in one region may critically depend on that of others (Martin and Sunley, 1998), as regions are part of larger economic systems with which they share growth and decline. Thus, the macroeconomic conditions of nations and the limitations imposed by participation in supranational monetary union may have

considerable influence on regional growth trajectories (Capello, 2013). Wider studies of development paths highlight that regional development trajectories are both interscalar (influenced by factors at wider geographical scales) and place-bound (dependent upon localized and regional factors), whilst institutional analyses elucidate the importance of the national level in support for urban and regional economies (Martinelli *et al.*, 2013).

As well as unpacking the role of the national level in shaping regional economic trajectories, the role of sectoral structures and their dynamics is critical. Much of the theorizing and empirical analysis of path dependence of regional economies has focused on the micro scale and specifically the study of how remnants and legacies of past, dominant regional industrial structures, institutions and human resources have shaped the evolutionary trajectories of particular technologies, firms, industries and sectors within regions (e.g. Neffke *et al.*, 2011). Regional trajectories are more complex than industrial or technological trajectories however ‘because the competencies of individual firms cannot be aggregated into a comprehensive, homogeneous regional development path’ (Bathelt and Boggs, 2003, p. 266). Regional development paths are in effect bundles of overlapping technological and industrial trajectories with complex evolutionary dynamics (Isaksen, 2015).

There is increasing recognition that a region’s industrial legacy will play an important role in shaping its future economic potential through influencing factors, such as the structure of local firms, wage costs, skills and business cultures, long after the industries themselves have gone (Martin *et al.*, 2016). A region’s capacity for adapting its industrial structure towards new technologies and growth sectors is seen as key to longer-term resilience (i.e. re-orientation and renewal), with the existence of ‘related variety’ or complementarity in sectors and technologies critical in providing greater opportunities for this (Boschma, 2015). The role of particular sectors in providing scope for short-term resilience is also coming under increasing scrutiny, with some evidence of an inverse relationship between the cyclical

sensitivity of sectors and growth for particular regions and particular national contexts. Thus, a region specializing in manufacturing may be more affected by an economic downturn than a region specializing in sectors such as public administration where demand and growth tends to be more stable and inelastic over time (Martin *et al.*, 2016; Courvisanos *et al.*, 2016). Whether these patterns hold true over longer time-periods and in comparative contexts remains to be seen.

In summary, existing literature reveals a growing interest in two key questions. The first of these is whether long-run regional growth paths or trajectories influence the resilience of a regional economy to a shock. Evolutionary theorizing in economic geography has highlighted the importance of the historical, path-dependent nature of regional development paths but there has been limited empirical analysis of how long-term trends relate to short-term cycles and shock responses. This demands that regional trajectories and resilience outcomes be clearly defined and measured. The second question is what kinds of trajectory are more or less likely to result in resilience to an economic crisis. Existing theorizing suggests regional trajectories are likely to exhibit certain critical features according to key geographical influences, notably the national economic system in which they reside, and their sectoral composition, which influences longer-term trends and cycle-sensitivity. This raises further methodological challenges in terms of whether significant groups of regions with similar growth trajectories can be empirically identified, to what extent regional growth trajectories are derivative of (or distinguishable from) their national contexts, and whether particular sectors play a role in shaping the trajectories most associated with resilience. The paper now proceeds to describe the data which we use to investigate the connection between regional resilience and the regional and national growth trajectory and then presents a set of approaches that are selected and developed to address these challenges.

### 3. Data and methodology

An analysis that investigates the connections between regional development trajectories, resilience outcomes and country affiliation requires output data that is hierarchical, temporal and consistently defined. For this analysis, data for Gross Value Added per worker (GVA per worker) (in 000s of €2000s) were obtained from Cambridge Econometrics. Their dataset contains annual observations for 28 countries between 1980 and 2012 inclusive, in aggregate and across sectors, and at four strictly hierarchical spatial scales: NUTS0 (i.e. country-level), 1, 2 and 3. There were some missing observations with data only available from 1990 onwards for Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia. Data for eight regions from the former East Germany were available from 1990 onwards while data for Flevoland were available after 1984. Due to a degree of spatial disconnection with the rest of Europe, we excluded data from our analysis that corresponds to the overseas territories of France (Guadeloupe, Martinique, French Guiana, La Réunion and Mayotte), Portugal (Azores and Madeira) and Spain (Ceuta, Melilla and the Canary Islands).

A matching data set containing annual employment data for the period 1990 to 2011, also obtained from Cambridge Econometrics, was used to identify the economic resilience of territories. The use of employment data as a measure of resilience is preferred to output measures because it reflects social and political preferences that tend to value employment over GVA as an indication of the health of an economy (Sensier *et al.*, 2016) and avoids the suggestion that the resilience of a region is simply a function of its growth path.

There is no single method that can be used to answer our substantive questions. It is therefore necessary to collate a set of approaches that interact with each other in order to formulate an integrated set of results which then highlight whether regions group together

according to the similarity of their growth paths, identify whether different administrative layers are important in shaping regional growth patterns, and categorize regions according to their resilience to an economic crisis. Here we draw on three novel though potentially integrated statistical approaches: trajectory analysis (Nagin, 2005), Bayesian multi-level regression (Rasbash *et al.*, 2009; Browne, 2009) and a recently developed method for measuring regional resilience (Sensier *et al.*, 2016).

### *Trajectory analysis*

Our first analytical task is to identify whether there are groups of regions that follow similar growth paths. Nagin's (2005) group-based trajectory approach is implemented here to identify if distinctive groups of regions follow similar productivity trajectories, to explore these productivity trajectories themselves and, most importantly for this article, to ascertain whether there are groups of regions that experience similar economic resilience outcomes.

Nagin's modeling approach permits the identification of groups of regions with distinctive trajectories that are not defined a priori but instead are conceived as latent and to be identified. This inductive approach allows for the identification of patterns and trends, and as group membership is conceived probabilistically and not as a deterministic outcome then the results show the probability that each region belongs to an identified group. Technical details of this method are provided in appendix 1 (available online).

### *Multi-level regression analysis*

Our second analytical task is to identify whether regional growth paths are governed by their hierarchical affiliation within regional and national borders. For example, if whole countries

suffer due to a recession and experience a five percent drop in growth across the board then particular regions within the country who were growing at only two percent per annum could now be experiencing a growth rate of minus three percent while regions that were growing at six percent per year could now be experiencing a growth rate of one percent. Moreover, if policies employed at the national level, such as fiscal expenditures, affect particular sectors more than others, such as tourism vs. finance, then the spatial effect of national policies could influence regional resilience and affect evolutionary growth patterns asymmetrically.

Application of multi-level time-series-cross-section regression (Rasbash *et al.*, 2009) using Bayesian Monte Carlo Markov Chains (Browne, 2009) permits a simultaneous examination of the extent to which the evolution of regional productivity was influenced by productivity evolutions at higher spatial scales, including the national level. Moreover, as regions are unlikely to be independent and identically distributed from each other and instead have a degree of evolutionary correlation when they are from the same country, account should be made of this hierarchical structure in order to avoid biased results. Here we apply multi-level regression not specifically to obtain time coefficient estimates but instead to gather empirical evidence that indicates whether the hierarchical affiliation of regions affects regional productivity evolutions and whether initial regional productivity values affect subsequent regional productivity evolutions. Such information is readily available from multi-level regression outputs, with information on the former attainable from estimating variance partition coefficients and for the latter from estimates of the intercept. Technical details on this method are provided in appendix 2 (available online).

Although scholars have contributed significantly to the analysis of within distributional dynamics in the growth literature (e.g. Quah, 1993; Durlauf *et al.*, 2005), to our knowledge there are no studies that have examined the similarity of growth trajectories for groups of economies with hierarchical spatial definitions from a resilience perspective.

### *Measuring resilience outcomes*

Our third analytical task is to identify whether particular paths identified using trajectory analysis are related to particular regional resilience outcomes. For this analysis we define resilience as the ability of an economy to maintain existing levels of economic activity in the face of an economic shock, or to recover to the pre-shock peak within three years. As such, we draw upon Sensier *et al.* (2016) and identify regions as either *resistant*, *recovered*, *not recovered (upturn)* and *not recovered (downturn)*.

Where a growth trajectory is associated more strongly with a particular resilience state than might be expected given the average distribution of resilience then a value greater than 100 will be recorded. The higher the value the greater the extent to which that resilience state is over-represented. In contrast, values of less than 100 signal where a growth trajectory is less associated with a particular resilience trajectory than would be expected given the overall distribution. Values close to or equal to 100 suggest that a particular trajectory is neither more nor less likely to have influenced the distribution of resilience states.

## **4. Results**

Applications of this novel set of statistical approaches to European GVA per worker data reveal evolutionary growth paths shaped by hierarchical economic structures and industrial sectors that have led to different regional economic resilience outcomes.



### *Multi-level regression results*

Spatial hierarchies may be important for the evolution of GVA per worker and it is opportune to assess the extent to which sub-national evolutions are associated with their national evolutions. The hierarchy of the NUTS classification permits the identification of the extent to which change is attributable to regional-specific idiosyncrasies. Application of model (2) to GVA per worker data using Bayesian Monte Carlo Markov Chains (chain length = 50,000) generates the results presented in table 1. These results highlight a number of important issues. First, the initial value of GVA per worker is associated with the subsequent evolution ( $\beta_0=40.961$ ,  $\text{std.err}=2.697$ ), which corroborates the suggestion that path dependence is important for a region's evolution (Martin and Sunley, 2006). There are positive variance estimates at all spatial levels, implying that there are large differences in GVA per worker at NUTS 0, 1, 2 and 3 levels. These VPC estimates imply that 75 percent of the variation in GVA per worker at the NUTS3 level was attributable to country level variation over this time period, which indicates that regional productivity evolutions are primarily determined by national level attributes (including policies), and that only 25 percent of the average NUTS3 region's evolution is determined at the sub-national level.<sup>1</sup> Although this evidence unequivocally suggests that national evolutions matter the most for local GVA per worker evolutions, the relative importance of sub-national administrative levels is likely to vary across countries according to the influence of policy making and the embeddedness and competitiveness of industries, firms, workers and capital at each spatial scale.

{Table 1}

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<sup>1</sup> Out of this sub-national proportion, 35.1 percent is attributable to the NUTS1 level, 39.5 percent attributable to the NUTS2 level and 25.4 percent is attributable to the NUTS3 level.

The time variance estimates at different spatial scales imply that GVA per worker values evolve differentially at each spatial level. The variance-covariance estimate at the country level is positive [ $\sigma_{v01}=3.653$ ,  $\text{std.err}=1.983$ ] suggesting that there is a tendency towards national-level divergence. The stability tests presented in Appendix 3 (available online) verify that the national level is crucially important in shaping sub-national output trajectories. Taken together, these results suggest that GVA per worker evolves in complex and interwoven ways across spatial scales and that sub-national analysis that pays close attention to evolutionary properties at all spatial scales is needed to understand regional development trajectories.

#### *Trajectory analysis: NUTS0*

Application of model (1) to country level GVA per worker data reveals groups of countries that have followed distinct productivity trajectories, as shown in figure 1 with their memberships listed in table 2.<sup>2</sup> Each profile represents the growth trajectory of the countries within a group where each profile's intercept is based on the average initial productivity value within that group. Although all countries within a group grow at a similar rate as denoted by the dynamic profile slope, around this line is a spread of countries that vary in distance from this mean-average trend line. For ease of interpretation, time has been mean-centered around 1997 (year 18 within our 33 year analyses).

{Figure 1 and table 2}

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<sup>2</sup> For brevity, group memberships are not provided for analyses at other spatial scales but are available on request from the authors.

These results reveal the presence of four groups of countries that have evolved in slightly different ways across the entire productivity distribution. There is evidence of a multi-speed Europe with the turbulent and fast growing countries of Ireland, Luxembourg and Norway included in group 4 compared with the European core countries in group 3, Mediterranean countries in group 2 and eastern European countries in group 1. Group 4 has accelerated away from the European core countries since the early 1990s albeit with more variable evolutions in the 1980s and late 2000s, which is probably a reflection of oil price considerations for Norway, pro-cyclical patterns of exports and foreign direct investment in Ireland and the dominance of the banking sector in Luxembourg. It is noticeable that all trajectories experienced a flattening of the slope around the 2007-2008 financial crisis.

The gap between groups 2 and 3 was relatively small in 1980 and this widened over this period due to relatively slow growth of group 2 countries. The trajectory for group 3 is more linear than for the other groups, although there is a notable kink in the trajectory for group 2 in 2007. Even though these four groups are following distinct trajectories, it does appear that the effects of the recent economic crisis have been widespread.

#### *Regional data: NUTS1 and NUTS2*

National level trends conceal variations in regional evolutionary behavior. For example, it is well known that there are many examples of regions that perform poorly (e.g. Cornwall and the Isles of Scilly, UK) or well (e.g. Île de France, France) in terms of productivity relative other regions within their countries.<sup>3</sup> There are also examples of border regions that are inherently entwined with the economy of their national neighbors (e.g. Basque country in Spain linked to France). Applications of model (1) to NUTS1 and NUTS2 regional level data

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<sup>3</sup> It is possible that these are outcomes of the modifiable areal unit problem; see Openshaw (1983).

reveal the presence of five and six groups, respectively, as shown in figures 2 and 3. The majority of NUTS2 regions are members of groups 3 (38.3%) and 4 (24.3%), representing 62.6% of the sample. There is evidence of emerging cleavages, with both groups 6 and 5 and groups 1 and 2 diverging from each other throughout much of the period. There is also evidence of divergence between groups 4 and 5 after the mid-1990s.

{Figures 2 and 3}

A number of important points emerge from this analysis. First, the lower the spatial scale of analysis then the easier it is to identify groups that have experienced downturns in their trajectories. This suggests there is merit in exploring resilience at the NUTS3 scale. Although most of the trajectories of NUTS2 regions exhibit either a dip or a flattening in their trajectory around the 2008 recession, there are few similarities in their post-recession trajectories. Visual inspection of figure 3 reveals four types of group: i) groups 1 and 5 did not experience a major dip in the recession and continued to grow, albeit at a slightly slower rate, ii) groups 2 and 4 experienced a dip but did recover albeit relatively slowly, iii) group 3 experienced a dip and then returned to pre-recession levels fairly quickly, and iv) group 6 experienced a decline that was not reversed in this time period.

Membership of these groups is not confined to regions from specific countries, nor are regions within countries confined to a specific group. For example, in the NUTS2 data (figure 3), Lincolnshire and Cornwall and the Isles of Scilly are in group 2; Cheshire, Bedford and Hertfordshire, Berkshire, Buckinghamshire and Oxfordshire, Surrey, East and West Sussex, Gloucestershire, Wiltshire and Bristol/Bath area, South Western Scotland and North Eastern Scotland are in group 4; Inner London is the only constituent member of group 6; and the remaining UK NUTS2 regions are in group 3. Such geographic spread is reminiscent of

diverse levels of importance of distinct industries for specific regional economies, and we attend to this point in more depth below.

The results presented in this section highlight that there was a plethora of experiences for NUTS2 regional economies in response to the recent recession. It highlights that there were important differences across regions and that country affiliation did not insulate all regions in the same way.

### *Resilience*

The discussion above highlights that the lower the spatial scale of analysis then the greater the ability to identify geographical areas that have experienced a downwards trajectory of GVA per worker. This subsection focuses on NUTS3 classified regions, which is the lowest spatial scale in our data. To analyze the associations between growth trajectories and employment resilience at this level, we first estimate the growth trajectories of NUTS3 regions (N=1307) and then identify the proportion of the regions within each trajectory that exhibit different degrees of resilience (*Resistant, Recovered, Not recovered: upturn* and *Not recovered: downturn*), as measured using employment data.<sup>4</sup>

As the multilevel regression analysis indicated that about 75 percent of the variation in GVA per worker at the NUTS3 level was attributable to the NUTS0 level, we split our sample of NUTS3 regions into four depending on the country-level membership identified in figure 1 and table 2. This approach has the advantage of being consistent with the analysis above while appreciating that a further 16.4 percent of the evolution of GVA per worker at the NUTS3 level is due to local characteristics. Trajectories of NUTS3 regions that are

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<sup>4</sup> See appendix 3 for comparable results of the resilience state of NUTS0 and NUTS2 regions (available online).

members of these four national-level clusters are presented in figures 4-7. This time the trajectories are presented in growth rates to highlight the rate of increase of GVA per worker. From here we assess whether different degrees of resilience are under or over-represented in each trajectory relative to their incidence across the population within the country-level trajectory cluster; hence, this analytical strategy permits the identification of NUTS3 evolutions set within country-cluster evolutions. The corresponding analysis of employment resilience is presented in table 3.

{Figures 4 – 7 and table 3}

It is possible to delve deeper into these NUTS3 trajectory analyses and identify associations between sector employment shares and the trajectory slope. Augmentation of the trajectory regression models to assess the correlations between sector employment share data at time  $t$  with GVA per worker growth rate data between periods  $t$  and  $t+1$  generates the results presented in table 4. Initially all trajectory regressions included employment variables for all sectors (with sector K as the base category) and then a general-to-specific econometric approach was followed to reduce the number of employment variables to only those that have a statistically significant effect.

{Table 4}

Cluster 1 consists of 199 localities from nine countries and the trajectory analysis reveals two subsidiary groupings. Regions in subsidiary group 2 were much less resilient to the economic crisis than those in subsidiary group 1 (table 3) and followed a cyclical trajectory with a more chaotic amplitude such that their growth rates were faster in the early

1990s and mid-2000s and slower around the turn of the millennium and after the 2007-2008 recession (figure 4). This is evidence that more stable trajectories improve subsequent resilience to shocks. Table 4 highlights that greater employment in sector A (agriculture, forestry and fishing) reduced the likelihood of a reduction in growth rates for regions in both trajectories, potentially because these products are less responsive to a business cycle. Regions with greater employment in sectors B-E (raw materials, food, textiles, printing, machinery, vehicles and utilities) and R-U (creative arts, sports activities and personal services) experienced greater downturns in economic growth, potentially because demand for these products is more responsive to the business cycle and disposable income. Where regions had greater employment numbers in sectors O-Q (public services) there was also less downward pressure on growth rates, potentially because these services are less responsive to changes in disposable income. Together, these results suggest that regions with greater employment in sectors where demand for products is more stable over time (food, public services, etc.) experienced smaller cyclical effects and were more resilient to the economic crisis than those regions that had greater employment in sectors where demand for products was more likely to experience a cut in demand in recessions.

In contrast, the three subsidiary trajectories of cluster 2 do not appear to exert a strong influence on the observed resilience of the 94 localities concerned (see panel B of table 3). None of the localities resisted the crisis and few either recovered or had experienced an upturn in employment and were on their way to recovery. Those that had recovered were all found in subsidiary trajectory 2 (figure 5). Countries included in cluster 2 have NUTS3 regions that followed three distinctly different trajectories. Included in this cluster are Greece and Portugal which both experienced severe difficulties in the recent recession. We were unable to identify the relative importance of employment shares on growth trajectories for

this cluster, potentially because of the relative importance of national issues and much greater variation in NUTS3 trajectories over this time period.

Countries included in cluster 3 had NUTS3 regions that experienced three trajectories which converged over time (figure 6) and their resilience rates are shown in panel C of table 3. This was the most numerous cluster group, comprising 986 NUTS3 regions, with the vast majority found in subsidiary group 2. Subsidiary groups 1 (31 localities) and 3 (39 localities) were less resilient to the 2007-2008 crisis than trajectory group 2, which on average experienced positive growth rates over the entire time period. This is further evidence that more stable trajectories improve subsequent resilience to shocks. Regions in trajectory 3 experienced an earlier downturn in economic activity and recovered earlier, while regions in trajectory 1 experience a later downturn and recovered later. Table 4 suggests regions in cluster 2 were more resilient to downturns when they had greater numbers of employment in sectors A (agriculture, forestry and fishing), J (publishing and communications), L (real estate) and O-Q (public services) but experienced greater downturns if they had larger employment numbers in sectors F (construction), G-I (transport and postal activities), M-N (legal services, architectural, travel agencies and security) and R-U (creative arts, sports activities and personal services). Again this suggests that localities with high shares of employment in sectors where demand is less responsive to consumer confidence are more resilient to downturns. It also highlights that a larger real estate sector (potentially indicating agglomeration effects) sustained the boom whereas a larger construction sector exacerbated the downturn.

The trajectories of subsidiary groups in cluster 4 (figure 7) and the corresponding resilience analysis (panel D in table 3) demonstrates the importance of national effects on NUTS3 localities. Comprised of localities from Ireland, Norway and Luxembourg, two subsidiary groupings were identified. The localities that were resilient to the crisis (*Resistant*



and *Recovered*) were all located in subsidiary trajectory 2 and are found in Norway and Luxembourg. In contrast, the localities that have not yet recovered to their pre-crisis peak employment levels (*Not Recovered: Upturn* and *Not Recovered: Downturn*) are in Ireland. Greater employment in sector B-E (raw materials, food, textiles, printing, machinery, vehicles and utilities) reduces the rate of growth in subsidiary trajectory 2.

## **5. Discussion**

This paper has sought to explore two key questions: firstly, whether the long-run trajectories of regions before a crisis influence how resilient regions are to the crisis; and secondly, what kinds of trajectory are more or less likely to result in resilience to an economic crisis. To do this, a novel set of methodological approaches have been applied to identify and group long-run regional trajectories, and to categorize regions according to their resilience to the 2007-2008 economic crisis. Evidence has been provided that the evolution of regional growth trajectories is associated with a region's ability to be resistant to shocks. Furthermore, analysis has discerned the extent to which regional trajectories are influenced by the wider national context within which regions reside as well as their sectoral composition.

This analysis has contributed to the developing literature within evolutionary economic geography which asserts the importance of long-term growth and development trajectories in regional economic performance and resilience. First, the analytical method developed here has provided a new means of empirically identifying similarities between regional growth trajectories without assuming patterns are necessarily defined in terms of convergence. In this regard, there may be scope for the methods developed here to inform ongoing debates in the European Union and across the OECD regarding the categorization of regions into types (Dijkstra and Poelman, 2011). Our findings suggest that not only can

discernible groupings of regional trajectory be identified for trend analysis, but that these trajectories are path dependent, with prior productivity values being strongly associated with subsequent trajectories. Past evolutionary paths thus do appear to play a key role in shaping future trajectories, affirming the importance in evolutionary theorizing attached to inherited legacies and the need to understand long-term patterns in regional development.

A particularly strong result is that regional and sub-regional growth paths are heavily influenced by national growth trajectories, supporting the claims made by Capello (2013) regarding the importance of the national economic context on regional development trajectories. Regional growth paths are critically interscalar and strongly influenced by national patterns, aligning with much of evolutionary theorizing around the inter-scalar relationships which characterize complex systems (Boulton *et al.*, 2015). Our findings indicate that the influence of the national scale predominates, with about 75 percent of the evolution in GVA per worker at the NUTS3 level attributable to the national level. However, our results also suggest that ‘place-bound’ sub-national influences on growth paths may have significance at the NUTS3 and/or NUTS2 scales. Regions possess a degree of independence from their national state in terms of their growth paths but with only about 10 percent of the average NUTS3 regional evolution being region-specific. Further research is needed to better understand the nature and effects of this potential variation and to explore where and how regional factors work against the grain of national influences. Our analysis also finds evidence in support of a multi-speed Europe, with four distinct groups of national development trajectory evident in the recent past. Our analysis does not however find clear patterns of convergence in these trajectories, although all experienced a flattening of growth in the aftermath of the 2007-2008 crisis, further supporting the significance of the crisis and its widespread effects.

Our analysis also suggests that the regional evolutionary behavior of GVA per worker was strongly associated with the ability of a region to be resilient to the 2007-2008 economic crisis. In other words, certain regional trajectories were more likely to be associated with positive resilience outcomes in terms of their ability to either resist the shock in the first place, or experience rapid recovery from its effects. In particular, we have observed that those regions with more stable trajectories leading up to the crisis, were more likely to exhibit resilience to it – a finding which has potentially significant implications for economic management. However, the analysis also indicates the significance of the national economy in modulating resilience outcomes. This suggests that whilst there is some scope for regional (and sub-regional) action, economic resilience at the regional level is likely to be heavily influenced by actions and developments at the national scale and to be the outcome of a shared endeavor between regional and national levels.

Our analysis also found evidence of the importance of the sectoral constitution of regional economies to their resilience outcomes. NUTS 3 regions with greater employment shares in sectors that are less responsive to changes in demand (such as agriculture, education and public sectors) were more likely to experience more stable trajectories and be more resilient to the economic crisis. Similarly, regions with greater employment shares in sectors that are highly responsive to changes in demand (such as textiles, printing, vehicles, creative industries, arts and sports facilities) tended to experience greater fluctuations across the business cycle and be less resilient to the crisis. This suggests a possible role for greater demand-oriented interventions in support of regional resilience such as measures to promote greater industrial diversity and to enhance or support the role of the public sector in providing stability. There are important regional outliers within nations, which indicates a need for further research to identify characteristics, such as perhaps transportation infrastructure and supply chains, that adversely affect a region's resilience and make it more likely to deviate

from its national trend than fellow regions. Furthermore, our results emphasize the importance of the particular nature of the shock in determining its implications for regional resilience. The 2007-2008 global economic crisis had particularly negative consequences for regions with larger construction sectors.

## **6. Conclusions**

This paper has focused upon exploring the possibility that the differential resilience of regions to shocks such as the recent global economic crisis, is heavily influenced by the long-run trajectories they have exhibited before the crisis and their specific characteristics. As such, it has drawn upon developing evolutionary theorizing around the complex, contingent and non-linear nature of regional economic trajectories, as well as providing new insights into the degree to which they are influenced by spatially bounded elements and inherited industrial structures. We have provided evidence in support of Martin *et al.*'s (2016) assertion that long-run trends and shifts in regional economies, in both their industrial structures and locally specific conditions and factors across sectors, are key influences on the evolving geographies of resistance to and recovery from recessions. What emerges notably from our analysis is that the cycle-sensitivity of key sectors is particularly significant. Furthermore, we have affirmed the evolutionary view that regional trajectories are likely to differ considerably in comparative context, with only limited tendencies to demonstrate convergence.

This paper has contributed to evolutionary theorizing around the dialectical and cumulative nature of regional growth. The evidence corroborates Martin and Sunley's (2015) argument that the differential resilience of regions to shocks and long-run growth paths is shaped by successive major shocks and recoveries; it also corroborates Martin *et al.*, (2016) argument that regional cycles (and responses to downturns) are inextricably linked to longer-

term trajectories and trends. We provide evidence that historical trajectories of both national and regional growth do bear some relationship to observed regional resilience outcomes in relation to this economic crisis. We emphasize that this is particularly so at the national level, but is also the case for some regional and sub-regional growth trajectories. Not only do the results presented here corroborate the findings of Mastromarco and Woitek (2007) and Owyang *et al.* (2009) that the heterogeneity of regional business cycles mean that they are not always synchronized with their national ones, our analysis also demonstrates that the differential ability of territories to withstand or recover from economic shocks is shaped by their own idiosyncratic longer run growth paths just as these shocks can then in turn shape future growth paths.

This relationship does not hold everywhere however, illustrating that past growth paths are just one important contributory factor, perhaps of many, that shape regional economic resilience. This aligns with evolutionary approaches which emphasize that regions are complex systems and as such, any ‘regularities – patterns of relationships...are not like, and do not behave like fundamental laws of science’ (Boulton *et al.*, 2015, p. 99). Local contingencies of context will also have an important role to play as will emergent economic activities and sources of innovation. It is also important to note that the analysis here refers to resilience as resistance and recovery; understanding how past trajectories influence resilience as re-orientation and renewal requires further analysis.

This article asserts that regional economies have empirically identifiable long-run and path-dependent development trajectories which relate to their resilience to shocks (Martin and Sunley, 2015). But while this analysis highlights that past trajectories matter, it is important to acknowledge that this does not necessarily mean these trajectories can be expected to predict the future. In essence this article has drawn on probability-based clustering models over the 1980-2012 time period, but these clustered groups may have

members that change over a longer timeframe and as such these results need to be monitored on an ongoing basis. Understanding the composition of the groups and the key characteristics of their members thus represents a crucial area for further analysis and research. Regional growth trajectories are highly dynamic and future research needs to provide evidence to highlight policies and other interventions or developments that encourage less negative dynamic evolutions. Nevertheless, the trajectories highlighted here could inform policy makers about which regions may be at greater risk of being less resilient to the next economic shock. Future research could also investigate whether proximity effects matter when group membership cuts across national borders, identify if and where regions could work together in order to collectively adjust their group trajectory, and ascertain if and when particular group trajectories depend on the trajectories of other groups. All of this suggests this work has the potential to open up several new and exciting avenues for evolutionary regional research.

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**Table 1: Multi-level regression results**

		Estimate	Std. Err	VPC
$\beta_0$	Intercept	40.961	2.697	
$\beta_1$	Time	0.599	0.065	
$\sigma_v^2_0$	Intercept variance at country level	456.574	149.480	75.2%
$\sigma_{v01}$	Intercept-time covariance at country level	3.653	1.983	
$\sigma_v^2_1$	Time variance at country level	0.106	0.041	
$\sigma_u^2_0$	Intercept variance at NUTS1 level	53.087	14.787	8.7%
$\sigma_{u01}$	Intercept-time covariance at NUTS1 level	0.117	0.324	
$\sigma_u^2_1$	Time variance at NUTS1 level	0.044	0.013	
$\sigma_t^2_0$	Intercept variance at NUTS2 level	59.219	6.583	9.8%
$\sigma_{t01}$	Intercept-time covariance at NUTS2 level	1.143	0.168	
$\sigma_t^2_1$	Time variance at NUTS2 level	0.046	0.006	
$\sigma_e^2_0$	Intercept variance of error	37.943	0.449	6.3%
$\sigma_{e01}$	Intercept-time covariance of error	0.086	0.023	
$\sigma_e^2_1$	Time variance of error	0.146	0.005	
	Deviance	271,885		
	Observations	40,347		

**Table 2: Country-level group membership**

Gp	Country
4	Ireland, Luxembourg and Norway
3	Austria, Belgium, Denmark, Finland, France, Germany, Italy, The Netherlands, Spain, Sweden and United Kingdom
2	Cyprus, Greece, Malta, Portugal and Slovenia
1	Bulgaria, Czech Rep., Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia

**Table 3: Resilience and subsidiary trajectories**

	<i>Resistant</i>	<i>Recovered</i>	<i>Not Recovered: Upturn</i>	<i>Not Recovered: Downturn</i>
<b>A: Cluster 1</b> (9 countries, 199 NUTS3 regions)				
<b>1</b>	124.4	124.4	99.5	88.3
<b>2</b>	0.0	0.0	102.1	148.0
<b>B: Cluster 2</b> (5 countries, 94 NUTS3 regions)				
<b>1</b>	na	0.0	0.0	104.4
<b>2</b>	na	142.4	142.4	98.1
<b>3</b>	na	0.0	0.0	104.4
<b>C: Cluster 3</b> (11 countries, 986 NUTS3 regions)				
<b>1</b>	51.9	45.4	128.5	169.6
<b>2</b>	104.1	101.9	97.9	97.1
<b>3</b>	41.2	99.3	127.7	112.4
<b>D: Cluster 4</b> (3 countries, 28 NUTS3 regions)				
<b>1</b>	0.0	0.0	35.0	306.3
<b>2</b>	140.0	140.0	126.0	17.5

**Table 4: Sector effects**

Sector	Cluster 1		Cluster 3			Cluster 4	
	Traj 1	Traj 2	Traj 1	Traj 2	Traj 3	Traj 1	Traj 2
<b>A</b>	0.008** (0.004)	0.050*** (0.018)	0.083*** (0.020)	0.013*** (0.003)	- 0.104*** (0.039)	-	-
<b>B – E</b>	0.008 (0.007)	-0.061* (0.034)	-	-	-	0.006 (0.019)	-0.044** (0.018)
<b>F</b>	-	-	-0.134*** (0.050)	-0.010** (0.004)	-0.011 (0.014)	-	-
<b>G – I</b>	-	-	-0.061* (0.033)	- 0.004*** (0.002)	-0.010 (0.007)	-	-
<b>J</b>	-	-	0.188* (0.096)	0.072*** (0.010)	0.015 (0.057)	-	-
<b>K</b>	-	-	-	-	-	-	-
<b>L</b>	-	-	0.754 (0.664)	0.180*** (0.026)	-0.012 (0.144)	-	-
<b>M – N</b>	-	-	-0.090 (0.064)	- 0.038*** (0.007)	0.049* (0.026)	-	-
<b>O – Q</b>	-0.010 (0.013)	0.150*** (0.043)	0.068* (0.036)	0.011*** (0.002)	0.005 (0.006)	-	-
<b>R – U</b>	0.015 (0.048)	-0.385** (0.152)	0.032 (0.208)	- 0.050*** (0.008)	-0.025 (0.029)	-	-
<b>Sigma</b>	11.428*** (0.122)		4.140*** (0.017)			4.960*** (0.118)	

Notes: \*, \*\* and \*\*\* represent statistical significance at the 10, 5 and 1 percent levels respectively. Full information of the industries included in these sectors can be obtained from <http://www.camecon.com/EnergyEnvironment/EnergyEnvironmentEurope/ModellingCapability/E3ME/Sectors.aspx>. The industry classification applies to the European countries and is defined in terms of the official NACE Rev.2 classification.

**Figure 1: Country-level trajectories**

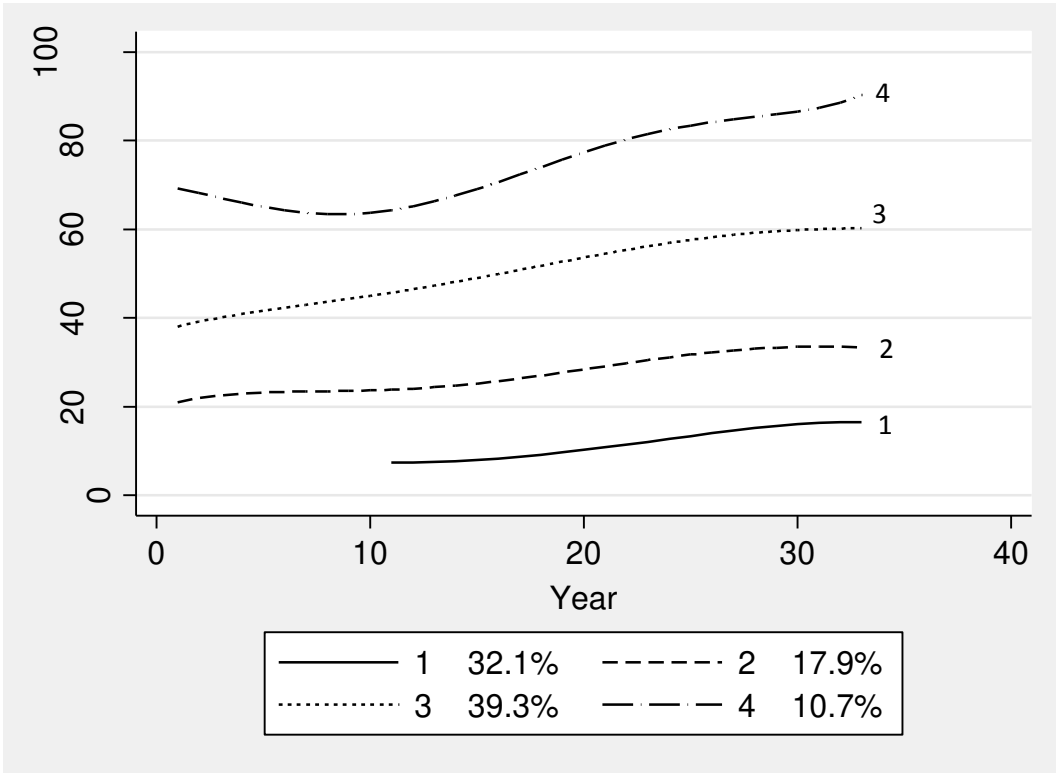


Figure 2: NUTS1-level trajectories

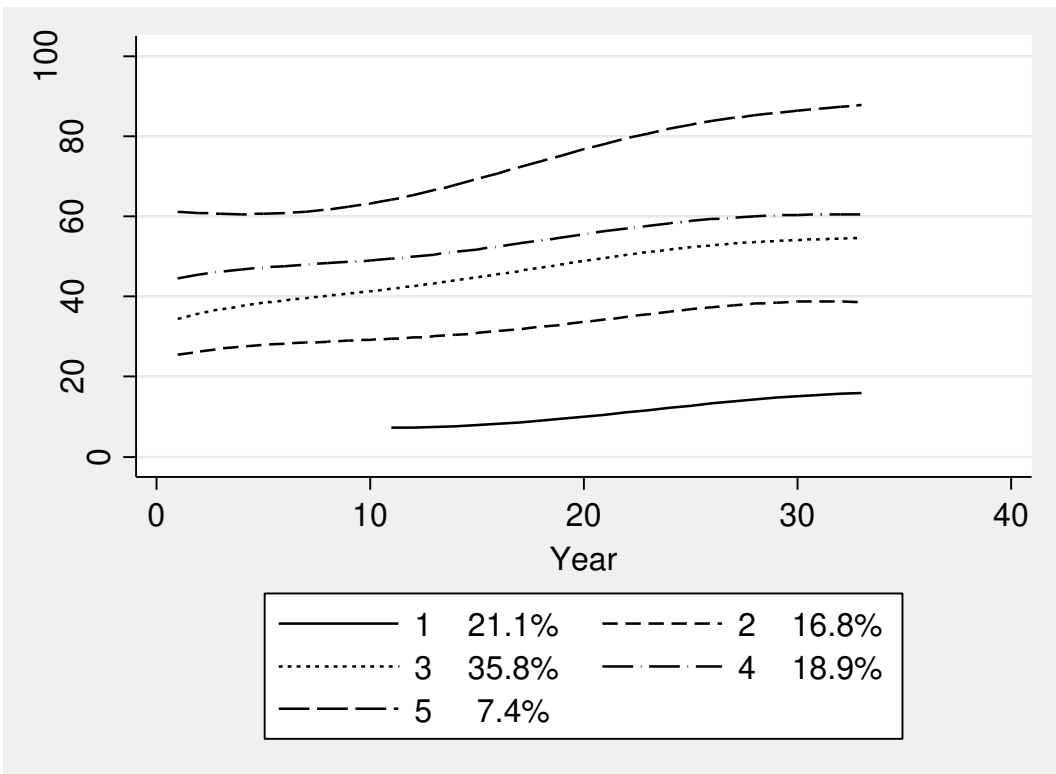
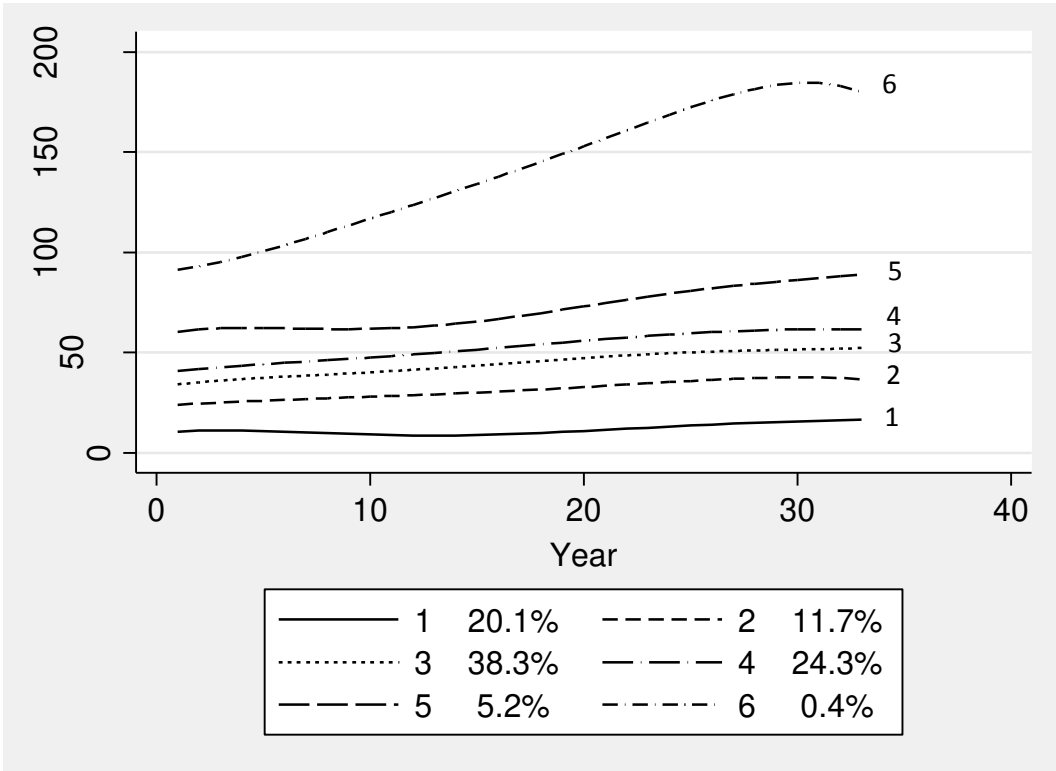
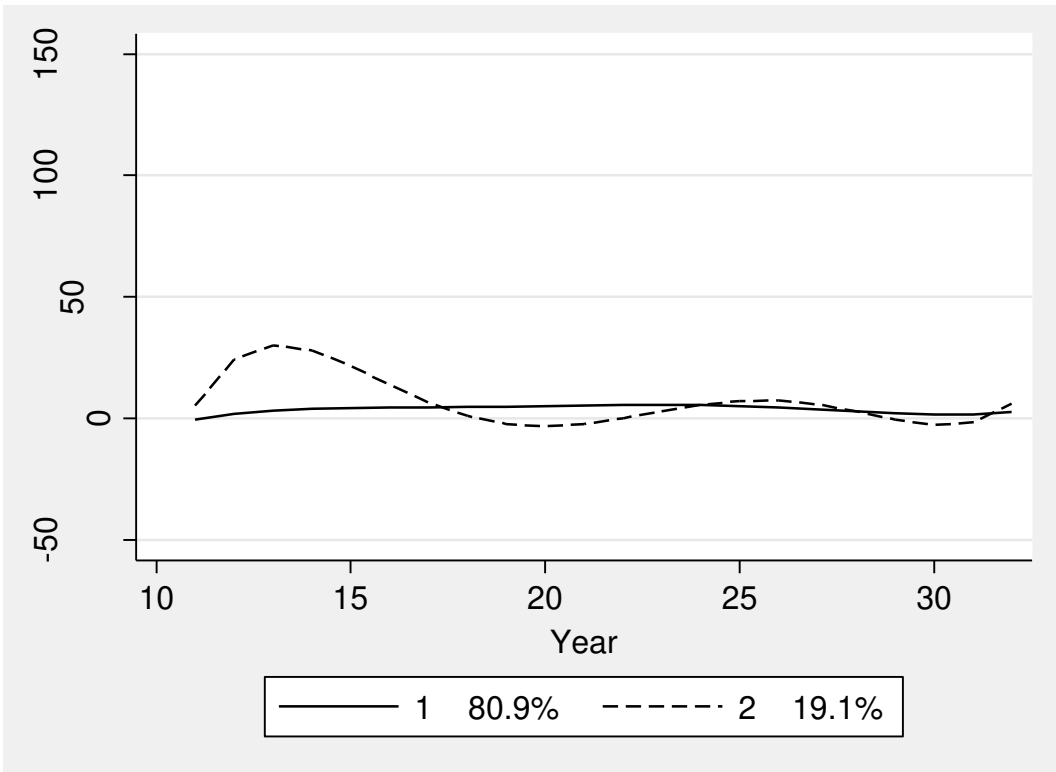


Figure 3: NUTS2-level trajectories



**Figure 4: NUTS3-level trajectories: cluster 1**



**Figure 5: NUTS3-level trajectories: cluster 2**

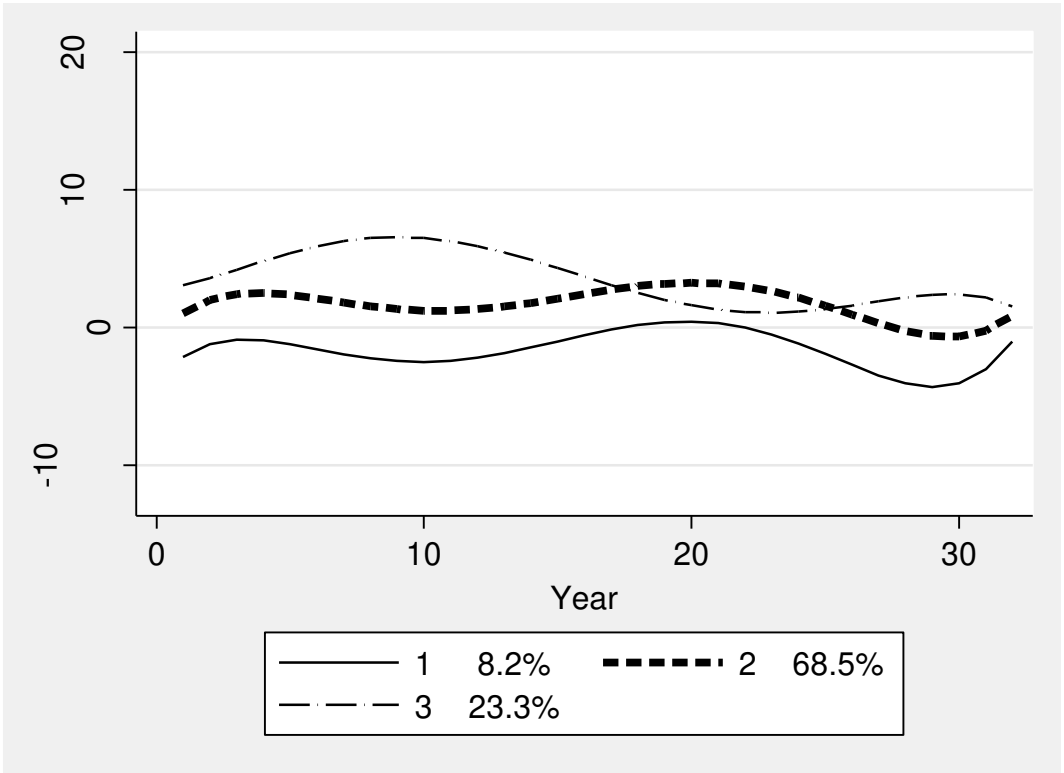


Figure 6: NUTS3-level trajectories: cluster 3

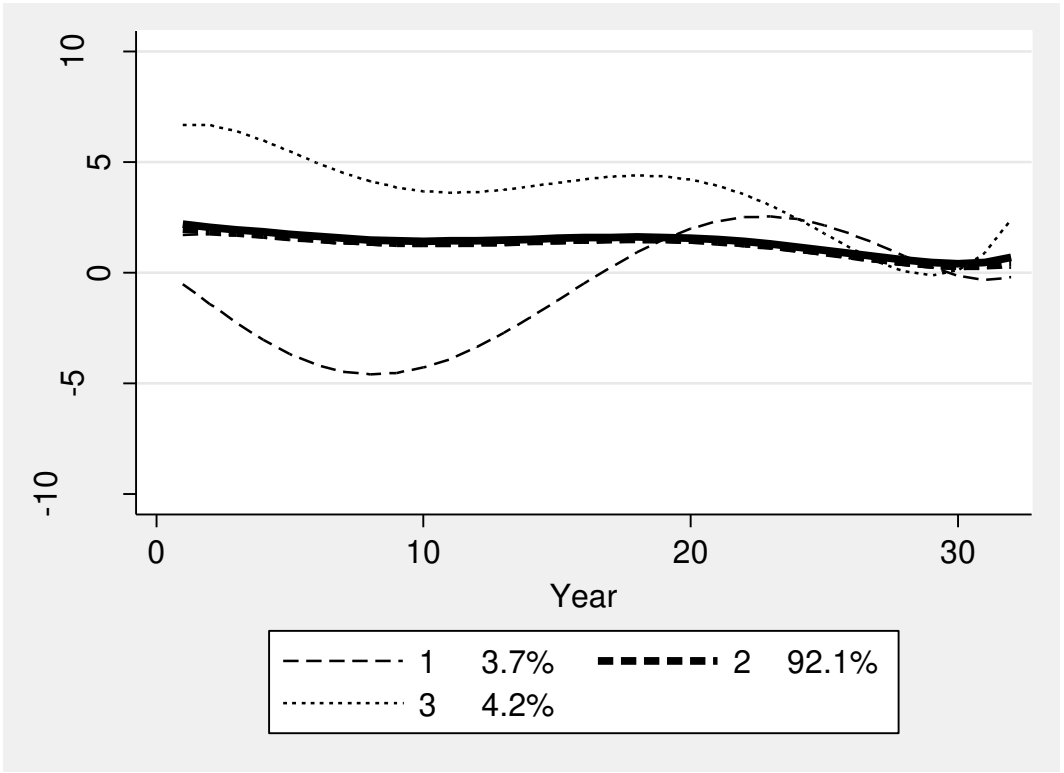
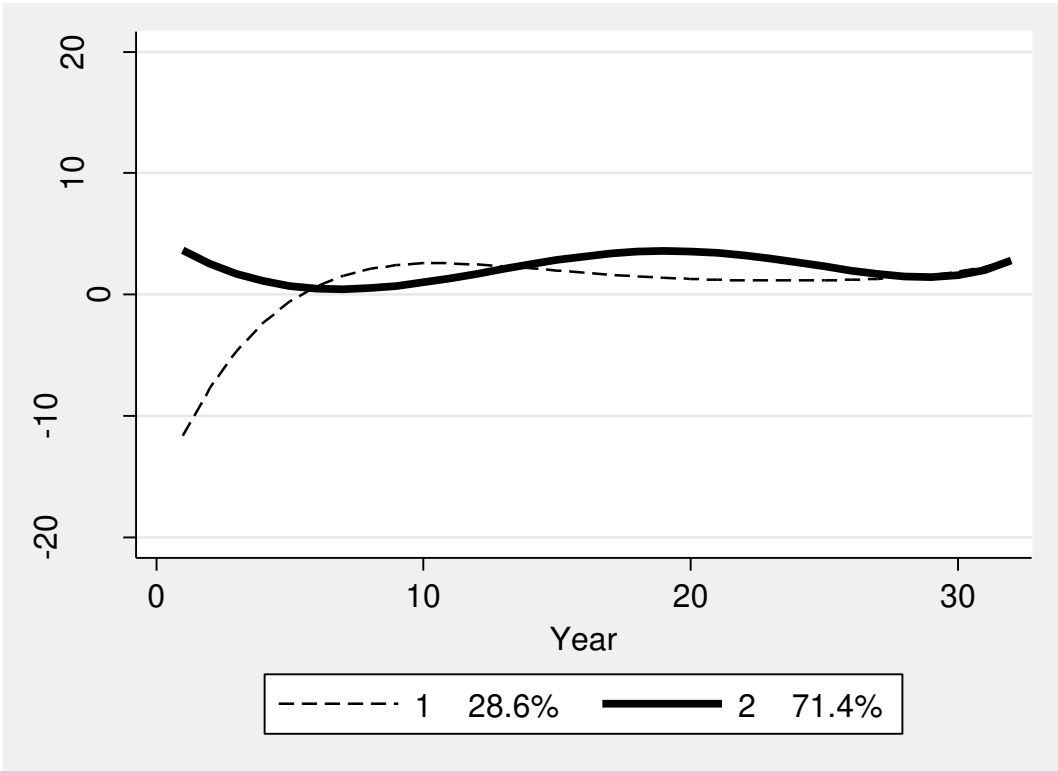


Figure 7: NUTS3-level trajectories: cluster 4



## Appendix 1: Nagin's trajectory approach

An unobserved group membership,  $Z_{jg}$ , is coded 1 if region  $j$  is in group  $g$  and 0 otherwise. The probability that region  $j$  belongs to group  $g$  is denoted by  $\pi_j^{(g)} = \Pr(Z_j = g)$ , where  $g = 1, \dots, G$ , with  $G$  signifying the total number of groups.  $Y_{ij}$  is an output measure for region  $j$  in year  $i$ , which depends on a set of time variables,  $T_{ij}$ . This model is appropriate when the expected value of  $Y$  changes smoothly as a function of a polynomial of time, and the question then arises concerning the order of polynomial to be used in analysis. As the time period encompasses about two recessions and two boom periods and as there is the need to incorporate regional paths that lack productivity resilience, we need to select a degree of polynomial that is complex enough to capture trends but not too complex that it compromises the ability to fit models reliably (as measured by the lowest value of the Bayesian Information Criterion (BIC)). For instance, a growth trajectory model with a fifth order polynomial of time can be written as:

$$\begin{aligned}
 y_{ij}^{(g)} &= \beta_{0j}^{(g)} Z_{jg} + \beta_1^{(g)} T_{ij} Z_{jg} + \beta_2^{(g)} T_{ij}^2 Z_{jg} + \beta_3^{(g)} T_{ij}^3 Z_{jg} + \beta_4^{(g)} T_{ij}^4 Z_{jg} + \beta_5^{(g)} T_{ij}^5 Z_{jg} + e_{ij} \\
 \beta_{0j}^{(g)} &= \beta_0^{(g)} + u_j^{(g)} \\
 u_j^{(g)} &\sim N(0, \sigma_u^{2(g)}) \\
 e_{ij} &\sim N(0, \sigma_e^2)
 \end{aligned} \tag{1}$$

where the  $\beta$ s in this model are regression coefficients which give the linear, quadratic, cubic, quartic and quintic relations between time and productivity. Superscript  $g$  indexes the unknown groups, each with a potentially different set of estimated  $\beta$ s and hence with distinctive trends. Two random terms are included that correspond to the unexplained variation:  $u_j$  is the between-region residual and  $e_{ij}$  is the within-region between-occasion residual. Assuming a normal distribution with zero mean, these residual terms can be summarized respectively in variance terms  $\sigma_u^{2(g)}$  and  $\sigma_e^2$ , where groups of regions are able to have different degrees of residual variability. Thus, application of Nagin's (2005) analytical method to regional output data can identify an efficient number of groups that have followed similar productivity trajectories.



## Appendix 2: Multi-level regression

The simplest four-level (i.e. NUTS0, 1, 2 and 3) hierarchical model of productivity with a time parameter,  $T$ , is:

$$\begin{aligned}y_{ijklm} &= \beta_{0ijklm} + \beta_{1ijklm}T_{ijklm} \\ \beta_{0ijklm} &= \beta_0 + h_{0m} + f_{0lm} + v_{0klm} + u_{0jklm} + e_{0ijklm} \\ \beta_{1ijklm} &= \beta_1 + h_{1m} + f_{1lm} + v_{1klm} + u_{1jklm} + e_{1ijklm}\end{aligned}\tag{2}$$

where  $y_{ijklm}$  is a measure of productivity for a NUTS3 region  $j$ , within NUTS2 region  $k$ , within NUTS1 region  $l$ , within country (i.e. NUTS0)  $m$  in year  $i$ . The random part of the model includes a linear time effect at all levels, so that the effect of time on productivity can be different at different spatial scales. A variance partition coefficient (VPC) can then be calculated to provide a statistical indication of the percentage of the evolution in regional-level productivity that is influenced by the different spatial levels, and is calculated as:

$$VPC = \frac{h_{0h}}{h_{0m} + f_{0lm} + v_{0klm} + u_{0jklm} + e_{0ijklm}}\tag{3}$$

where the numerator can be replaced by the estimate of the variance at any of the hierarchical spatial scales.

### Appendix 3:

A series of sensitivity tests were undertaken to identify whether the relative importance of the national and local level changes with the systematic exclusion of the other spatial scales. These results, displayed in table A1, highlight the stability of the importance of the national level in explaining the evolution at the NUTS3 level with only minor adjustments in the variance explained at the national scale once NUTS1 or NUTS2 data levels are excluded. Of course, the proportion originally explained at the NUTS1 and NUTS2 spatial scales needs to be apportioned to other spatial scales when they are excluded. The exclusion from the model of NUTS1 and NUTS2 spatial scales enhances the variance explained at both the NUTS0 and NUTS3 scales, but the apportionment of an additional 8.4 (10.1) percent to the NUTS0 (NUTS3) level only strengthens the argument that the majority of the variation in GVA per worker evolution at the NUTS3 scale is explained by the evolution of GVA per worker at the national scale.<sup>5</sup>

**Table A1: Variance partition coefficient estimates (%)**

Level	Full model	Excluding NUTS1	Excluding NUTS2	Excluding NUTS1 & NUTS2
NUTS0	75.2	76.5	74.0	83.6
NUTS1	8.7	–	14.8	–
NUTS2	9.8	16.3	–	–
NUTS3	6.3	7.2	11.2	16.4

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<sup>5</sup> Qualitatively similar inferences are made about GDPpw data.

#### Appendix 4:

It is opportune to mention the number of regions and countries that can be classified as *Resistant*, *Recovered*, *Not recovered: Upturn* and *Not Recovered: Downturn*, as presented in table A2. In terms of employment, three countries and 33 NUTS2 regions can be classified as *Resistant*, as they were able to maintain employment levels throughout the crisis, while four countries and 64 regions experienced a fall in employment but recovered to pre-crisis peak levels and can therefore be classified as being *Recovered*. Eleven countries and 85 regions experienced a fall in employment and are yet to recover to pre-crisis peak levels, although they did experience an upturn in employment (*Not recovered: Upturn*). A further nine countries and 88 regions had not recovered to pre-crisis peak levels by 2011 and had not experienced an upturn either (*Not Recovered: Downturn*).

**Table A2: Number of territorial units by resilience state**

	<i>Resistant</i>	<i>Recovered</i>	<i>Not Recovered: Upturn</i>	<i>Not Recovered: Downturn</i>	Total
NUTS0 National States	3	5	11	9	28
	Germany	Austria	Cyprus	Bulgaria	
	Luxembourg	Belgium	Czech Rep.	Denmark	
	Poland	Malta	Estonia	Spain	
		Norway	Finland	Greece	
		Sweden	France	Ireland	
			Hungary	Latvia	
			Italy	Portugal	
			Lithuania	Romania	
			The Netherlands	Slovenia	
			Slovakia		
			United Kingdom		
NUTS2 Regions	33	64	85	88	270