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Industrial Relatedness and Regional Resilience in the European Union

Abstract: The 2008 Great Recession prompted interest in the concept of regional resilience. This paper discusses and empirically investigates the relationship between industrial relatedness and economic resilience across European Union regions over the 2008-2012 crisis period. The analysis focuses on two types of industrial relatedness: technological and vertical (i.e. market-based). The empirical analysis is performed on a sample of 209 NUTS-2 regions in 16 countries. Our results highlight a positive effect of technological relatedness on the probability of resilience in the very short run (i.e. the 2008-2009 period), while the negative effect of vertical relatedness seems to persist for longer.

JEL Codes: B52; C25; O52; R11.

Keywords: Technological Relatedness; Vertical Relatedness; Regional Resilience; European Union.

1.INTRODUCTION

Interest in the notion of regional resilience was triggered by the Great Recession that occurred in 2008, and, since then, the different capacity of European regions to resist and absorb this type of external shock has been the focus of the scientific and policy debate.

Several different theoretical perspectives have been developed to investigate the concept of resilience and to identify the determinants of its geographic heterogeneity. Particularly relevant, from an economic geography perspective, is the evolutionary approach, which distinguishes two types of regional resilience: one defined as the short-term capacity of a region to absorb an external shock, and the other defined as the long-term capacity to develop new growth paths (Martin and Sunley, 2015). These two definitions share the idea that the industrial structure of a region, particularly its industry specialisation and industrial relatedness, plays a key role in shaping these processes.

Following the short-term evolutionary perspective, which emphasises the short-term capacity of a region to absorb an external shock, this paper investigates the relationship between industrial relatedness and economic resilience for a sample of European Union (EU) regions over the 2008-2012 crisis period. It considers two specific types of industrial relatedness: technological relatedness and vertical relatedness. The former captures situations where local industries exploit similar skills or inputs. For example, the level of technological relatedness (i.e. similarity) between two industries will increase with the similarity in the composition of their inputs. In such cases, technological similarity can have a positive effect on regional resilience since skills, capabilities and technologies can be re-allocated rapidly among industries, thus improving regional capacity to respond to an external shock. In contrast, vertical relatedness captures situations where local industries are connected through input-output relations. When a local productive system is highly vertically connected, even a sector-specific shock can have a negative effect on regional resilience through propagation mechanisms.

The empirical analysis is performed on a sample of 209 regions − defined at geographic level

2 of the *Nomenclature des Unités Territoriales Statistiques* (NUTS) – from 16 EU countries. Overall, our results suggest that technological relatedness has a positive effect on resilience in the very short run (i.e. the 2008-2009 period), while the negative effect of vertical relatedness seems to persist over a longer time horizon.

The paper is organised as follows. Section 2 discusses the related literature; Section 3 describes the dataset and the econometric methodology; Section 4 presents and discusses the empirical findings; and Section 5 concludes.

2. THEORETICAL FRAMEWORK

2.1. Resilience processes at the regional level

Resilience is a multi-faced concept which is defined in three different ways in the literature. The ecological literature defines regional resilience as the capacity of a region to move from one possible steady-state path to another without changing its structure, identity or function (Holling, 1973; Reggiani et al., 2002). The engineering approach defines resilience as the capacity of a region, following a shock, to return to a persistent steady-state equilibrium (Pimm, 1984; Rose, 2004; Fingleton et al., 2012). The evolutionary approach defines resilience as the ability of a region to adapt over the short run following a shock (Martin, 2012) or to develop new growth paths over the long run (Boschma, 2015). All these three definitions have in common the presence of a certain threatening event, that is, an external exogenous shock such as a natural disaster (e.g. the Northern Italy earthquake), a terroristic attack (e.g. the September 11 attacks), or an economic and financial crisis (e.g. the 2008 Great Recession).

Some of the recent literature analyses regional resilience empirically from two different perspectives: the country and the European level. At the country level, Fingleton et al. (2012) analyse the impact of major recessionary shocks on UK regional growth paths over the 1971-2010 period, and find that employment shocks have permanent effects on the focal region and that proximate regions suffer from spillover effects. Martin et al. (2016) show that the regional effects of recessions in the UK depend on the phase of the business cycle; they highlight how region-specific characteristics – particularly, the industry structure – are key determinants of resilience. Psycharis et al. (2014) and Giannakis and Bruggeman (2015) use shift-share and input-output models to show that rural regions in Greece are more resistant than urban regions, while Palaskas et al. (2015) find a positive effect of industrial specialisation on Greece's regional resilience. Similarly, Cuadrado-Roura and Maroto (2016) show that productive specialisation is important for improving regional resilience in the case of Spain. Cellini and Torrisi (2014) examine regional growth in Italy over the 1890-2009 period and, unlike Fingleton et al. (2012), find homogenous recovery behaviour, which explains the persistence of huge regional differences in Italy. Di Caro (2014, 2017) studies regional resilience in terms of employment in Italian regions and finds that the most resilient regions have the highest levels of industrial diversification – especially in manufacturing activities − and the highest human and social capital endowments. Lagravinese's (2015) results are similar for the resilience of Italian regions over the 1970-2011 period and when differentiating between Northern and Southern Italy in relation to performance and industry composition. Finally, Eraydin (2016) focuses on the weak effect of regional policies for improving Turkish regions' resistance to the crisis.

A second stream of empirical literature focusing on the resilience concept considers the European dimension. Some studies explain high regional resilience in relation to variables such as government expenditure and national trade patterns (Crescenzi et al., 2016) or the development of protectionist policies during the 1990s economic boom (Fratesi and Rodríguez-Pose, 2016). Other studies, instead, focus on region-specific characteristics and, particularly, the level of industrial specialisation, as key drivers of resilience (e.g. Brakman et al., 2015; Capello et al., 2015).

Overall, the empirical literature adds to our understanding of regional resilience by highlighting the heterogeneity of regional responses to external shocks. The previous contributions suggest that, when controlling for macroeconomic policy, infrastructure, human and social capital variables, the existing industry structure is the most important determinant of regional resilience.

2.2. Industrial relatedness and regional resilience

As already stated, the industry structure is generally considered the key determinant of regional resilience. Based on this, a new stream of research in economic geography provides more in depth analyses by focusing on a specific feature of the regional industry structure: the intensity of the production and technological relationships among sectors. This branch of the literature, which grew out of debate on related variety (Frenken et al., 2007), investigates the role played by industrial relatedness in terms of regional resilience, from two different time perspectives. According to the evolutionary approach (Boschma, 2015), industrial relatedness may have a positive effect on the ability of a region to absorb an external shock in the short run and to develop new growth paths over the long run.

Looking at the short-run effects of industrial relatedness, Balland et al. (2015) investigate the technological resilience of US cities over the 1975-2002 period. They find that cities that have knowledge bases with high levels of relatedness, in relation to the set of technologies in which they do not yet possess a comparative advantage, have a higher tendency to avoid crises and a greater capacity to limit the intensity and duration of crisis events. Diodato and Weterings (2015) use Dutch data on 12 regions and 59 sectors to investigate how the embeddedness of input-output linkages, skill relatedness and connectivity contribute jointly to the resilience of regional labour markets to economic shocks. They find that labour markets in centrally located and services-oriented regions show faster recovery regardless of the type of shock hitting the economy.

The long-run evolutionary approach to regional resilience is developed in Xiao et al. (2017). The key idea is that industrial relatedness may be a determinant of both long-run economic development and long-run regional resilience. Xiao et al. (2017) investigate the ability of 173 European regions to develop new industry specialisations following the 2008 Great Recession, assuming industrial relatedness as a main determinant of this ability. They propose four measures of industrial proximity: unrelated variety; related variety; industrial relatedness, measured as the average proximity among specialised industries with respect to the other industries located in the region; and technological relatedness, measured using a Los index. Their main finding is that, after the crisis, industrial relatedness had a positive effect on regional resilience only in the case of knowledge intensive sectors.

This paper focuses on short-term regional resilience and the role of industrial relatedness as a shock absorber. At the regional level, industrial relatedness can take different forms. First, local industries may require similar inputs, so that the level of technological relatedness among industries increases with the similarity in the composition of their inputs. Technological relatedness is expected to have a positive effect on regional resilience since skills, capabilities and technologies can be re-allocated rapidly across industries, thereby, improving the capacity of a region to respond to an external shock. Second, local industries may be connected in terms of input-output relations: if a local productive system is highly vertically connected, then even a sector-specific shock can have a negative effect on regional resilience through propagation mechanisms. For this reason, vertical relatedness is expected to have a negative effect on regional resilience.

3. EMPIRICAL FRAMEWORK

3.1. The dataset

The empirical analysis employs three main data sources available from Eurostat (Statistical Office of the European Communities): the *Structural Business Statistics* (SBS) database; the *European Union Labour Force Survey* (EU-LFS); and the *Regio* database.

The SBS is the main source of employment data disaggregated at the geographic NUTS-2 level and level 2 of the NACE Rev. 2 industry classification. However, the SBS data show a relevant number of missing values that account for about the 16.1% of the total number of observations. In order to overcome this issue, information from the SBS are integrated using employment data from the EU-LFS. Cleaning of the employment data was conducted in three steps. First, a series of linear interpolations of the SBS on the EU-LFS were run to cover missing values in the SBS, when data from both sources were available. This allows us to reduce the missing values to 7% for the entire sample. Second, if only data from the EU-LFS were available, missing data in the SBS were imputed using EU-LFS values adjusted for the average ratio between the EU-LFS and the SBS at the national level for any two-digit industry. This step allows us to reduce the number of missing values from 7% to 5%. Third, if neither of the first two options was feasible, missing values in the SBS were imputed using average national growth rates at the two-digit industry level.

At the end of the cleaning procedure, missing information was reduced to an average of 2.9% for the entire sample. In this way, the reliability of our results is likely to be improved for two main reasons. First, the empirical analysis is based on a larger number of employment data at sectoral level (i.e. two-digit level of the NACE Rev. 2 industry classification), which allows greater accuracy in estimating the measures of industrial relatedness. Second, the analysis is based on homogenous (in terms of sectoral composition) regional employment data for a sample of 209 NUTS-2 regions − for which other data from the *Regio* database were also available − in the following EU countries: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, Germany, Hungary, Italy, Poland, Portugal, Romania, Spain, Sweden, the Netherlands and the United Kingdom.

Table 1 shows the geographic structure of the sample and its representativeness. With the exceptions of the Finnish region of Åland, the Spanish autonomous cities of Ceuta and Melilla, and the German regions of Brandenburg-Nordost, Brandenburg-Südwest, Chemnitz and Leipzig, which were excluded due to unavailability of data, all NUTS-2 regions belonging to the listed countries are covered in the sample.[1]

[--- Table 1 ---]

[1] Based on data availability, the British NUTS-2 regions of Inner London-East and Inner London-West are aggregated into a unique region (Inner London). For the same reason, the British NUTS-2 regions of Outer London-East and North East, Outer London-South, and Outer London-West and North West are aggregated into a unique region (Outer London). Therefore, the sample covers the entire UK territory, although five NUTS-2 regions are aggregated into two larger regions.

3.2. The empirical model

The empirical analysis aims to evaluate whether and how a relationship between industrial − technological and vertical − relatedness and regional resilience exists. Economic resilience is defined over four periods between 2008 and 2012 following Lagravinese (2015):

$$Resilience_r^{T-t} = \frac{\left(\frac{E_r^T - E_r^t}{E_r^t}\right) - \left(\frac{E_c^T - E_c^t}{E_c^t}\right)}{\left|\frac{E_c^T - E_c^t}{E_c^t}\right|} \tag{1}$$

where E_r denotes employment in NUTS-2 region r, E_c denotes employment in the corresponding country c, $t = 2008$ and $T = 2009, \dots, 2012$. According to Equation (1), a region can show one of the following three patterns with respect to its country: (i) resilience if $Resilience_r^{T-t} > 0$; (ii) non-resilience if $Resilience_r^{T-t} < 0$; or (iii) neutrality if $Resilience_r^{T-t} = 0$.[2]

Table 2 shows that all the regions analysed present either strictly positive or strictly negative values. Resilience presents an inverted U-shaped temporal pattern: the number of resilient regions slightly increased between the one- and three-year periods (from 47.4% to 48.8%), and decreased between the three- and four-year periods by a lower percentage than for the one-year period (from 48.8% to 44%). This pattern is relevant, in particular, to those regions belonging to non-Euro Zone countries.

[--- Table 2 ---]

The dichotomous pattern of resilience highlighted in Table 2 – that is, an absence of neutral

[2] Regional resilience can be measured using "simple" or "composite" indicators. According to Martin (2012) and Martin and Sunley (2015), a suitable simple indicator to evaluate a region's resistance to recessions is the ratio of the drop in regional employment (or output) and the respective drop for the country as a whole. This indicator is slightly modified in Lagravinese (2015) to account better for asymmetric behaviours among regions over a longer period. In the context of composite indicators, the procedure used to select the variables ranges from identification based on a literature study (e.g. Briguglio et al., 2009; Cardona et al., 2008; Cutter et al., 2008; Foster, 2011) to statistical analysis based on factor analysis (e.g. Graziano, 2013).

regions in the sample − allows us to specify the following binary dependent variable:

$$R_r^{T-t} = \begin{cases} 0, & if Resilience_r^{T-t} < 0 \\ 1, & if\ Resilience_r^{T-t} > 0 \end{cases} \qquad (2)$$

such that a region is resilient over a period $T - t$ if $R_r^{T-t} = 1$, and is not resilient if $R_r^{T-t} = 0$.

Figure 1 maps the spatial distribution of the binary variable capturing resilience (R_r^{T-t}) over the periods 2008-2009 and 2008-2012. Comparison of the maps shows clearly that spatial clusters of resilient regions are present in each country, and that they seem to become more well-defined over the four-year period – for example, Northern and Central Spanish regions, North-Eastern and Central Italian regions, South-Eastern British regions.

[--- Figure 1 ---]

The binary nature of the dependent variable requires specification of a probabilistic model. Specifically, regional resilience is modelled through a Logit model of the form (Cameron and Trivedi, 2005):

$$Pr(y^{T-t} = 1|\boldsymbol{x}) = \Lambda(\boldsymbol{x}'\boldsymbol{\beta}) = \frac{e^{\boldsymbol{x}'\boldsymbol{\beta}}}{1 + e^{\boldsymbol{x}'\boldsymbol{\beta}}} \qquad (3)$$

where $\Lambda(\cdot)$ is the cumulative distribution function of the logistic distribution, the term $\boldsymbol{x}'$ denotes a vector of the (log-transformed) continuous explanatory variables − which include two measures of industrial relatedness and a set of region-specific controls − plus a set of country dummy variables, and the term $\boldsymbol{\beta}$ denotes the vector of the associated parameters to be estimated. Equation (3) is estimated via Maximum Likelihood (ML).

3.3. Measuring industrial relatedness

The key explanatory variables capture the level of technological and vertical industrial relatedness in region r at time $t = 2008$. Following Los (2000) and Frenken et al. (2007), the variable capturing technological relatedness is defined on the basis of a symmetric matrix derived from the 2008 national input-output tables provided by Eurostat. As in Los (2000), the technological proximity between each pair of industries i and j (ω_{ij}^t) is based on the similarity of the inputs purchased by industries i and j from any industry k:

$$\omega_{ij}^t = \frac{\sum_{k=1}^n s_{ik}^t \cdot s_{jk}^t}{\sqrt{\left[\sum_{k=1}^n (s_{ik}^t)^2 \cdot \sum_{k=1}^n \left(s_{jk}^t\right)^2\right]}} \tag{4}$$

where s_{ik}^t and s_{jk}^t denote the respective share of inputs acquired from industry k by industries i and j. By definition, the diagonal elements of the similarity matrix are equal to 1. The weights (ω_{ij}^t) of the technological proximity matrix are calculated for each pair of industries such that they take a value close to 1, the greater the similarity in the composition of the inputs of the two industries. The technological relatedness variable is calculated as follows:

$$Technological\ Relatedness_r^t = \frac{\sum_{i=1}^n \sum_{j=1}^n \left(E_{ri}^t \cdot E_{rj}^t \cdot \omega_{ij}^t\right)}{\sum_{i=1}^n \sum_{j=1}^n \left(E_{ri}^t \cdot E_{rj}^t\right)} \tag{5}$$

where E_{ri}^t and E_{rj}^t denote employment in region r at time $t = 2008$ in industries i and j, respectively, and ω_{ij}^t denotes the weight capturing the technological proximity between industries i and j. The technological relatedness variable ranges in the interval $[(1/n), 1]$, and reaches its maximum value of 1 if a region is specialised in a unique industry or if is characterised by the presence of a cluster of "technological equivalent industries" (Frenken et al., 2007, p. 691).

Following the same rationale, the variable capturing vertical relatedness is defined as follows

(Cainelli et al., 2016):

$$Vertical\ Relatedness_r^t = \frac{\sum_{i=1}^{n}\left[\left(E_{ri}^t \cdot s_{ii}^t\right) + \sum_{j=1}^{n}\left(E_{rj}^t \cdot s_{ij}^t\right)\right]}{\sum_{i=1}^{n}\left(E_{ri}^t + \sum_{j=1}^{n} E_{rj}^t\right)} \tag{6}$$

where s_{ii}^t denotes the share of inputs industry i buys from itself, while s_{ij}^t denotes the share of inputs industry i buys from any industry j, with $i \neq j$. The variable capturing vertical relatedness ranges in the interval $[0,1)$, where $0 \leq s_{ii}^t \leq 1$ and $0 \leq s_{ij}^t \leq 1$ with $\sum_i^n s_{ij}^t = 1$, and is increasing in the number of input-output related industries co-localised within a region r.

Figure 2 maps the spatial distribution of the variables capturing technological and vertical relatedness. It is interesting to note that these two variables present a clear spatial pattern.

[--- Figure 2 ---]

3.4. Control variables

The set of region-specific control variables includes: a measure of industrial concentration ($Industrial\ Concentration_r^t$) defined as a Herfindahl-Hirschman index using employment data and aimed at controlling for an "industrial portfolio" effect; a proxy for region size defined in terms of population ($Population_r^t$); a measure of employment density ($Employment\ Density_r^t$) defined as employment per square kilometre and aimed at capturing the effect of agglomeration forces; a measure of labour productivity ($Labour\ Productivity_r^t$) defined as Gross Domestic Product (GDP) per employee to capture the region's efficiency level; and the variable for unemployment rate ($Unemployment\ Rate_r^t$) aimed at capturing some characteristics of the regional labour market.

Table 3 presents descriptive statistics for the industrial relatedness and control variables, while Tables 4 and 5 present descriptive statistics of the log-transformed explanatory variables and their correlation coefficients, respectively.

[--- Table 3 ---]

[--- Table 4 ---]

[--- Table 5 ---]

4. EMPIRICAL RESULTS

Table 6 reports the average marginal effects on the resilience probability, estimated over four time periods between 2008 and 2012. Technological relatedness seems to have a positive effect on the resilience probability only over the 2008-2009 period, while vertical relatedness has a negative effect over all periods considered. This suggests that regions characterised by a high level of market-based transactions among industries suffered a contagion effect, which seems to have been time persistent during the crisis period. It emerges also that the resilience probability is increased by an "industry portfolio" effect, such that regions characterised by high levels of industrial diversification are more likely to react better than their national counterparts. Finally, structural, region-specific factors that seem to increase the regional resilience probability include agglomeration-type forces − captured by the employment density variable − and efficiency − captured by the labour productivity variable. In contrast, a high unemployment rate and a large region size seem to have a negative effect on the region's resilience probability.

[--- Table 6 ---]

Figure 3 plots the marginal effects of technological and vertical relatedness on the one- and four-year period resilience probabilities. The plots confirm the results reported in Table 6: while technological relatedness presents a positive and increasing marginal effect only for the 2008-2009 period, vertical relatedness presents a negative marginal effect for both periods.

[--- Figure 3 ---]

Table 7 shows that the results change if regions belong to countries that are part or not of the Euro Zone. First, the positive effect of technological relatedness over the 2008-2009 period is confirmed for regions in the Euro Zone. Second, technological relatedness seems to have a positive effect on the 2008-2011 period resilience probability of non-Euro Zone regions. Finally, the negative effect of vertical relatedness is particularly relevant only for the most integrated regions, that is, those belonging to the Euro Zone, while it characterises only the 2008-2010 and 2008-2011 periods resilience probability of non-Euro Zone regions.

[--- Table 7 ---]

Table 8 reports the results for the sample split according to four categories of crisis behaviour. In each period, the regions can be (i) highly non-resilient, (ii) non-resilient, (iii) resilient, or (iv) highly resilient, according to the value observed in Equation (1). Specifically, the distribution of the variable $Resilience_r^{T-t}$ is split into two quantiles for strictly negative values, and into two quantiles for strictly positive values, over the four periods of resilience considered. A Multinomial Logit model is estimated for each period considered, with the outcome "highly non-resilient" as the reference category. Looking at the estimated average marginal effects on the probability of being (i) highly non-resilient, (ii) non-resilient, (iii) resilient, and (iv) highly resilient, it can be seen that technological relatedness seems to reduce the probability of being highly non-resilient over the 2008-2010, 2008-2011 and 2008-2012 periods, while it seems to reduce the probability of being non-resilient only over the 2008-2009 period. However, it seems to increase the probability of being highly resilient only in the short run. Overall, vertical relatedness seems to increase (highly) non-resilient behaviour over all periods. On the contrary, it seems to decrease the probability of being resilient only over the 2008-2010 period, while it seems to decrease the probability of being highly resilient over all periods.

[--- Table 8 ---]

5. CONCLUSIONS

Regional resilience is probably one of the most important issues in economic geography and, particularly, resilience related to the effects of the 2008 Great Recession. The evolutionary approach to regional resilience emphasises the role played by the region's current industry structure as a (potential) determinant of its capacity to absorb an external shock in the short run or to develop new growth paths in the long run (Martin and Sunley, 2015).

This paper contributes to this debate by adopting a short-run evolutionary perspective to an empirical investigation of the relationship between industrial (i.e. technological and vertical) relatedness and short-run regional resilience for a sample of EU regions.

The results suggest that technological relatedness has a positive effect on the resilience probability in the very short run, i.e. over the 2008-2009 period, while the negative effect of vertical relatedness seems to persist over a longer time horizon. We also show that industrial diversification increases the probability of regional resilience.

These findings may have some interesting implications. Regions characterised by similar technologies, that is, by high levels of technological relatedness, show high levels of resilience. The key mechanism here seems to be an "inputs' market pooling" effect: inputs freed up by one or more industries affected by an external shock can be rapidly re-allocated to other industries. This is possible only if regional industries have a similar technological base. Our evidence would suggest that this mechanism works only in the very short run and that, after a certain period of time, a saturation effect seems to prevail. In contrast, the degree of vertical connection among regional industries seems to have a negative and persistent effect on regional resilience. In this case, propagation mechanisms in input-output relations work to amplify the negative effect of an external shock, significantly reducing regional capacity for resilience. Finally, as expected, the diversification of the productive structure seems to have a positive effect on the capacity of a region to resist to an external shock such as an economic crisis.

In spite of the fact that this paper emphasises the role played by the region's industry structure as a key determinant of regional resilience, other factors can have a role in this process. Some of them are strictly related to the experiences that a region can have accumulated during previous crises, while others may be related to specific active policies that national or regional governments can have implemented in order to weaken the effect of the Great Recession. For example, Möller (2010) shows how measures of within-firm flexibility supported by labour market instruments, such as short-time schemes, have had a role in weakening the effects of the Great Recession in many German regions.

In conclusion, this paper has emphasised the role of specific industrial structure characteristics in explaining economic resilience at regional level in Europe. It is worth noting that these characteristics are often the result of a long-run historical process with strong local idiosyncratic features. In other words, history matters in defining not only the productive specialisation pattern of a region, but also its ability to efficiently and rapidly respond to an external shock such as an economic crisis.

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TABLES

Table 1. Countries covered and sample representativeness.

Country	Regions	Regions in the sample	Percentage covered
Austria	9	9	100.00
Belgium	11	11	100.00
Bulgaria	6	6	100.00
Czech Republic	8	8	100.00
Denmark	5	5	100.00
Finland	5	4	80.00
Germany	39	35	89.74
Hungary	7	7	100.00
Italy	21	21	100.00
Poland	16	16	100.00
Portugal	7	7	100.00
Romania	8	8	100.00
Spain	19	17	89.47
Sweden	8	8	100.00
The Netherlands	12	12	100.00
United Kingdom	40	35	87.50
Total	221	209	94.57

Table 2. Structure of resilient regions.

Period	$Resilience_r^{T-t}$	Total Sample	Euro Zone	
			Yes	No
	>0	99	59	40
2008-2009	<0	110	57	53
	$=0$	0	0	0
	>0	102	62	40
2008-2010	<0	107	54	53
	$=0$	0	0	0
	>0	102	61	41
2008-2011	<0	107	55	52
	$=0$	0	0	0
	>0	92	59	33
2008-2012	<0	117	57	60
	$=0$	0	0	0

Table 3. Descriptive statistics of explanatory variables.

	Mean	Std. Dev.	Min.	Max.
Technological Relatedness$_r^t$	0.302	0.035	0.201	0.392
Vertical Relatedness$_r^t$	0.019	0.002	0.013	0.023
Vertical Relatedness (Los)$_r^t$	0.028	0.005	0.015	0.047
Industrial Concentration$_r^t$	0.068	0.015	0.047	0.131
Population$_r^t$	1,858,942	1,411,226	125,550	9,469,841
Employment Density$_r^t$	102.084	221.702	0.818	1984.199
Labour Productivity$_r^t$	0.091	0.035	0.015	0.202
Unemployment Rate$_r^t$	6.433	3.082	1.900	17.700

Table 4. Descriptive statistics of log-transformed explanatory variables.

	Mean	Std. Dev.	Min.	Max.
Technological Relatedness$_r^t$	-1.206	0.120	-1.604	-0.937
Vertical Relatedness$_r^t$	-3.957	0.093	-4.305	-3.760
Vertical Relatedness (Los)$_r^t$	-3.591	0.176	-4.173	-3.062
Industrial Concentration$_r^t$	-2.707	0.202	-3.052	-2.033
Population$_r^t$	14.188	0.726	11.740	16.064
Employment Density$_r^t$	3.772	1.215	-0.201	7.593
Labour Productivity$_r^t$	-2.503	0.515	-4.227	-1.597
Unemployment Rate$_r^t$	-2.850	0.463	-3.963	-1.732

Table 5. Correlation matrix among log-transformed explanatory variables.

		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Technological Relatedness$_r^t$	[1]	1							
Vertical Relatedness$_r^t$	[2]	-0.062	1						
Vertical Relatedness (Los)$_r^t$	[3]	-0.059	0.557	1					
Industrial Concentration$_r^t$	[4]	0.391	-0.076	0.594	1				
Population$_r^t$	[5]	-0.074	-0.089	-0.109	-0.271	1			
Employment Density$_r^t$	[6]	0.088	0.232	0.076	-0.138	0.338	1		
Labour Productivity$_r^t$	[7]	0.048	0.075	-0.115	-0.042	-0.112	0.264	1	
Unemployment Rate$_r^t$	[8]	0.079	-0.261	0.045	0.164	0.216	-0.133	-0.119	1

Table 6. Industrial relatedness and resilience probability: average marginal effects.

Resilience Period	2008-2009	2008-2010	2008-2011	2008-2012
Technological Relatedness$_r^t$	1.836**	0.969	1.226	0.618
	(0.764)	(0.789)	(0.768)	(0.740)
Vertical Relatedness$_r^t$	-2.266****	-3.312****	-2.450****	-2.922****
	(0.622)	(0.604)	(0.631)	(0.607)
Industrial Concentration$_r^t$	-1.360****	-1.288****	-1.334****	-0.827**
	(0.369)	(0.364)	(0.366)	(0.356)
Population$_r^t$	-0.146**	-0.100*	-0.199****	-0.084
	(0.060)	(0.060)	(0.060)	(0.059)
Employment Density$_r^t$	0.051	0.132***	0.100**	0.113***
	(0.040)	(0.043)	(0.043)	(0.043)
Labour Productivity$_r^t$	0.984***	1.288****	1.127****	1.169****
	(0.330)	(0.337)	(0.331)	(0.333)
Unemployment Rate$_r^t$	-0.142	-0.210**	-0.225**	-0.296****
	(0.093)	(0.091)	(0.089)	(0.085)
Country Dummies	Yes	Yes	Yes	Yes
No. NUTS-2 Regions	209	209	209	209
Wald Test (χ^2, [p-value]	33.05 [0.061]	38.55 [0.022]	37.27 [0.030]	39.49 [0.018]
Log Likelihood	-117.30	-111.81	-113.53	-110.62
Pseudo R^2	0.19	0.23	0.22	0.23
LR Test (χ^2, [p-value]	54.56 [0.000]	66.00 [0.000]	62.55 [0.000]	65.50 [9.000]

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$. All specifications include a constant term. All explanatory variables are log-transformed. LR denotes the likelihood-ratio test with respect to the constant-only model.

Table 7. Average marginal effects by Euro Zone countries.

Group of Countries	Euro Zone							
	No				Yes			
Resilience Period	2008-2009	2008-2010	2008-2011	2008-2012	2008-2009	2008-2010	2008-2011	2008-2012
Technological Relatedness$_r^t$	1.776	1.211	3.370**	2.160	1.859**	0.621	0.253	-0.036
	(1.281)	(1.410)	(1.523)	(1.366)	(0.938)	(0.957)	(0.912)	(0.926)
Vertical Relatedness$_r^t$	-0.007	-2.951***	-2.190*	-1.494	-3.555****	-3.290****	-1.826**	-3.311****
	(1.139)	(1.009)	(1.117)	(0.994)	(0.756)	(0.813)	(0.820)	(0.817)
Industrial Concentration$_r^t$	-0.922	-1.668**	-1.585**	-0.852	-1.311***	-1.055**	-1.168***	-0.809*
	(0.740)	(0.652)	(0.736)	(0.656)	(0.427)	(0.435)	(0.419)	(0.444)
Population$_r^t$	0.024	-0.167	-0.198	0.056	-0.163**	-0.093	-0.194***	-0.122*
	(0.131)	(0.133)	(0.139)	(0.122)	(0.067)	(0.069)	(0.065)	(0.070)
Employment Density$_r^t$	0.060	0.300****	0.154*	0.127*	0.055	0.072	0.068	0.097*
	(0.064)	(0.082)	(0.083)	(0.076)	(0.051)	(0.056)	(0.052)	(0.055)
Labour Productivity$_r^t$	-0.532	1.461**	0.535	0.725	1.732****	1.186***	1.161***	1.088**
	(0.657)	(0.570)	(0.681)	(0.586)	(0.398)	(0.409)	(0.422)	(0.428)
Unemployment Rate$_r^t$	-0.463***	-0.647****	-0.431***	-0.475***	-0.237*	-0.117	-0.075	-0.214*
	(0.167)	(0.145)	(0.155)	(0.145)	(0.123)	(0.133)	(0.130)	(0.129)
Country Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. NUTS-2 Regions	93	93	93	93	116	116	116	116
Pseudo R^2	0.18	0.41	0.25	0.35	0.30	0.19	0.23	0.19

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$. All specifications include a constant term. All explanatory variables are log-transformed.

Table 8. Industrial relatedness and resilience probability: average marginal effects on resilience categories.

Resilience Category	Highly Non-Resilient				Non-Resilient			
Resilience Period	2008-2009	2008-2010	2008-2011	2008-2012	2008-2009	2008-2010	2008-2011	2008-2012
Technological Relatedness$_r^t$	-0.580	-1.640**	-1.474**	-1.663**	-1.173*	0.642	0.301	1.015
	(0.710)	(0.689)	(0.668)	(0.716)	(0.668)	(0.682)	(0.667)	(0.701)
Vertical Relatedness$_r^t$	1.343**	2.047****	2.424****	1.997****	0.890*	1.303**	0.229	1.045*
	(0.615)	(0.617)	(0.582)	(0.564)	(0.524)	(0.570)	(0.583)	(0.595)
Industrial Concentration$_r^t$	0.700**	1.140***	1.073***	1.278****	0.637*	0.250	0.311	-0.348
	(0.337)	(0.354)	(0.335)	(0.361)	(0.329)	(0.332)	(0.341)	(0.362)
Population$_r^t$	0.105*	0.089*	0.018	-0.038	0.043	0.024	0.201****	0.141**
	(0.057)	(0.053)	(0.049)	(0.052)	(0.053)	(0.054)	(0.057)	(0.057)
Employment Density$_r^t$	-0.044	-0.079*	-0.079**	-0.044	-0.015	-0.060	-0.033	-0.076*
	(0.039)	(0.041)	(0.038)	(0.039)	(0.036)	(0.042)	(0.040)	(0.040)
Labour Productivity$_r^t$	-0.760**	-0.440	-0.799***	-0.799**	-0.219	-0.912***	-0.431	-0.432
	(0.349)	(0.297)	(0.292)	(0.323)	(0.302)	(0.346)	(0.326)	(0.351)
Unemployment Rate$_r^t$	0.049	0.204***	0.254****	0.297****	0.105	-0.021	-0.025	-0.003
	(0.082)	(0.076)	(0.070)	(0.067)	(0.085)	(0.082)	(0.085)	(0.091)
Country Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. NUTS-2 Regions	55	54	54	59	55	53	53	58
Log Likelihood	-211.00	-218.98	-205.89	-198.77	-211.00	-218.98	-205.89	-198.77
Pseudo R^2	0.27	0.24	0.29	0.31	0.27	0.24	0.29	0.31
LR Test (χ^2, [p-value]	156.88 [0.000]	141.39 [0.000]	167.56 [0.000]	178.93 [0.000]	156.88 [0.000]	141.39 [0.000]	167.56 [0.000]	178.93 [0.000]

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$. The table reports the estimated average marginal effects on the probability of being (1) highly non-resilient, (2) non-resilient, (3) resilient or (4) highly resilient obtained from the estimation of a multinomial logistic regression with outcome "highly non-resilient" as reference category. All specifications include a constant term. All explanatory variables are log-transformed. LR denotes the likelihood-ratio test with respect to the constant-only model.

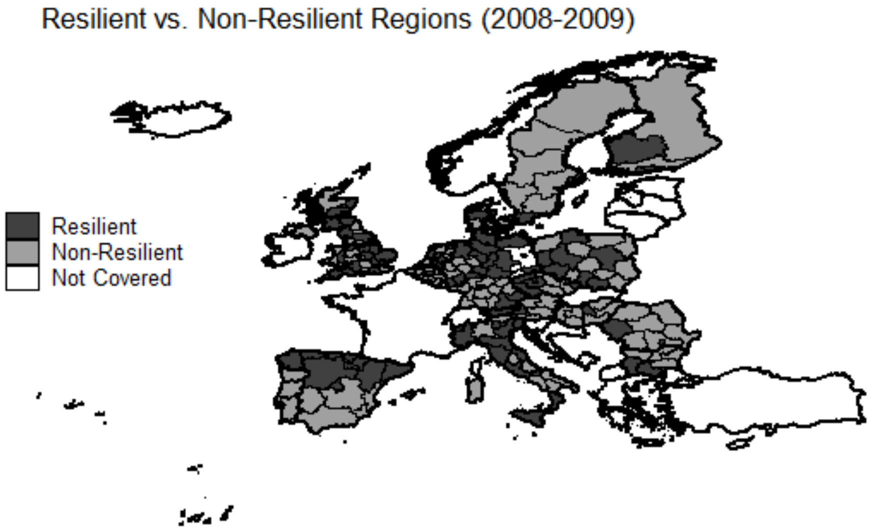
Table 8 − Continues.

Resilience Category	Resilient				Highly Resilient			
Resilience Period	2008-2009	2008-2010	2008-2011	2008-2012	2008-2009	2008-2010	2008-2011	2008-2012
Technological Relatedness$_r^t$	0.499	-0.099	0.648	0.097	1.254**	1.097*	0.525	0.552
	(0.629)	(0.656)	(0.622)	(0.617)	(0.631)	(0.647)	(0.640)	(0.613)
Vertical Relatedness$_r^t$	-0.727	-1.103*	-0.431	-0.761	-1.506***	-2.246****	-2.221****	-2.280****
	(0.550)	(0.569)	(0.507)	(0.513)	(0.564)	(0.534)	(0.558)	(0.568)
Industrial Concentration$_r^t$	-0.856***	-0.459	-0.530*	-0.439	-0.481	-0.931***	-0.853***	-0.490
	(0.325)	(0.318)	(0.299)	(0.293)	(0.324)	(0.322)	(0.318)	(0.298)
Population$_r^t$	-0.034	0.010	-0.059	-0.016	-0.114**	-0.123**	-0.160***	-0.087*
	(0.052)	(0.051)	(0.049)	(0.048)	(0.052)	(0.051)	(0.051)	(0.048)
Employment Density$_r^t$	0.023	0.085**	0.031	0.006	0.036	0.054	0.081**	0.114***
	(0.032)	(0.036)	(0.033)	(0.035)	(0.036)	(0.033)	(0.036)	(0.037)
Labour Productivity$_r^t$	0.710***	0.393	0.507*	0.249	0.269	0.960****	0.723***	0.982****
	(0.269)	(0.288)	(0.268)	(0.295)	(0.284)	(0.270)	(0.269)	(0.273)
Unemployment Rate$_r^t$	-0.136	-0.089	-0.075	-0.073	-0.019	-0.094	-0.154**	-0.221***
	(0.085)	(0.084)	(0.080)	(0.082)	(0.074)	(0.076)	(0.074)	(0.071)
Country Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. NUTS-2 Regions	50	51	51	46	49	51	51	46
Log Likelihood	-211.00	-218.98	-205.89	-198.77	-211.00	-218.98	-205.89	-198.77
Pseudo R^2	0.27	0.24	0.29	0.31	0.27	0.24	0.29	0.31
LR Test (χ^2, [p-value]	156.88 [0.000]	141.39 [0.000]	167.56 [0.000]	178.93 [0.000]	156.88 [0.000]	141.39 [0.000]	167.56 [0.000]	178.93 [0.000]

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$. The table reports the estimated average marginal effects on the probability of being (1) highly non-resilient, (2) non-resilient, (3) resilient or (4) highly resilient obtained from the estimation of a multinomial logistic regression with outcome "highly non-resilient" as reference category. All specifications include a constant term. All explanatory variables are log-transformed. LR denotes the likelihood-ratio test with respect to the constant-only model.

FIGURES

Figure 1. Spatial distribution of resilient and non-resilient regions.



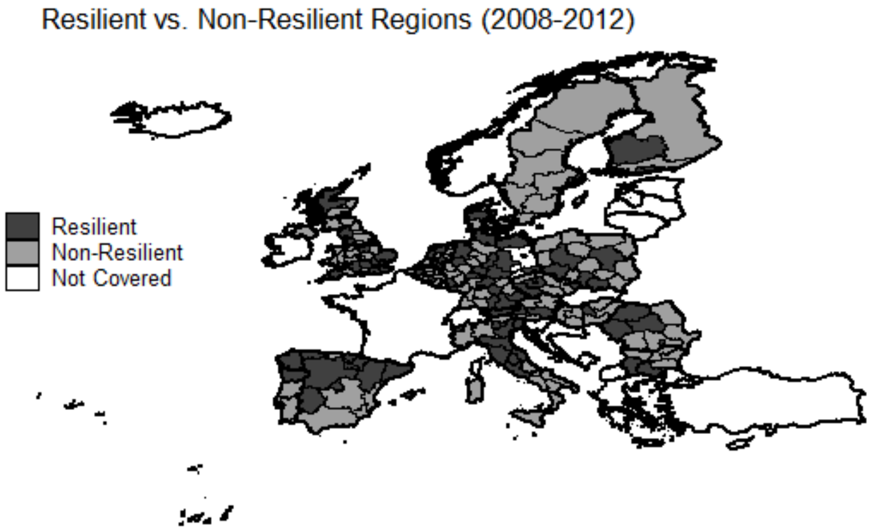


Figure 2. Spatial distribution of industrial relatedness variables.

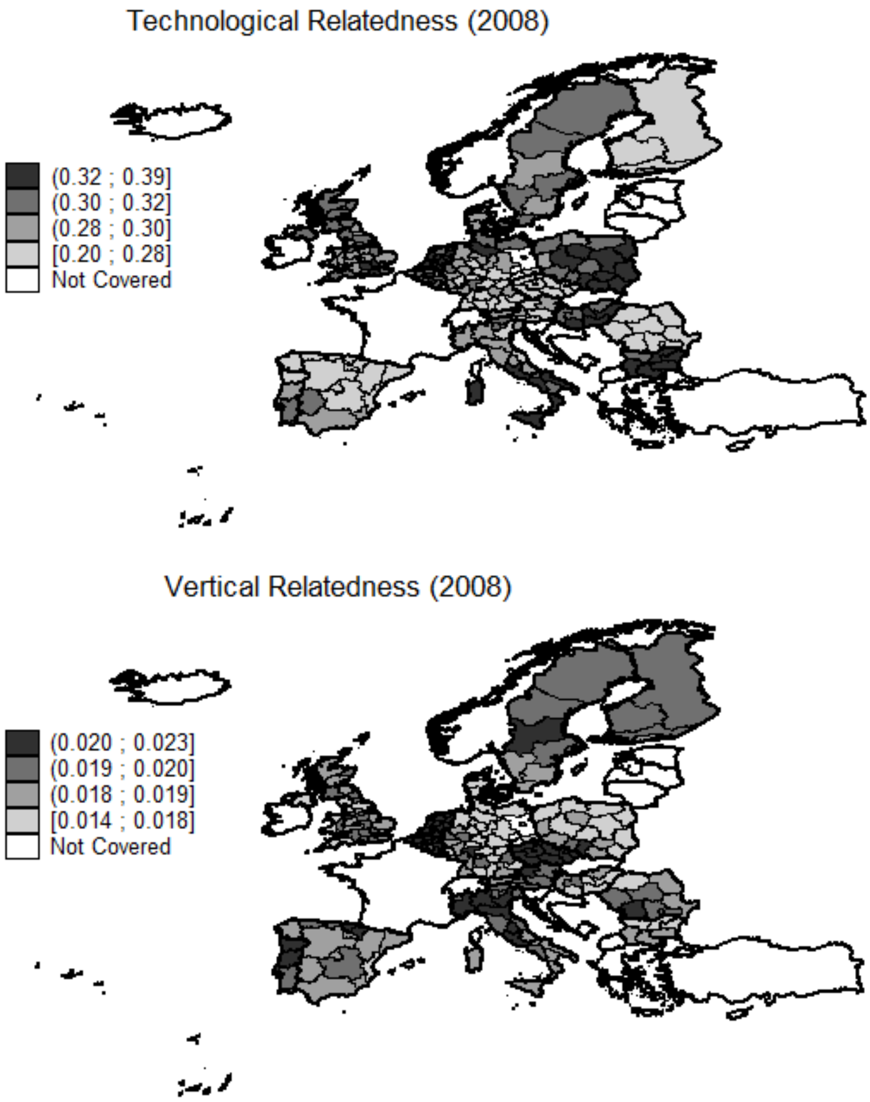
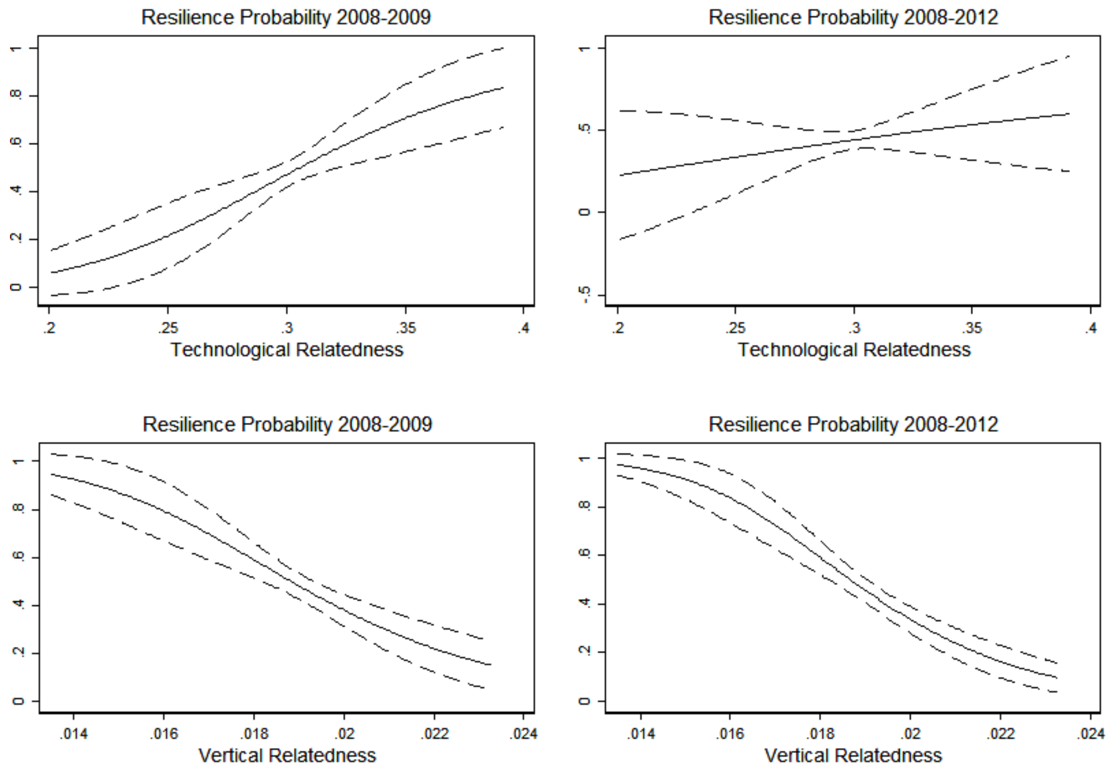


Figure 3. Marginal effects of technological and vertical relatedness on resilience probability.



Notes: Plots refer to the estimated average marginal effects reported in columns (1) and (4) of Table 4.