Assessment of adaptive economic resilience of Greek regions

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Abstract. *This study assesses Greek NUTS II regions' adaptive economic resilience during the 2007–2009 economic disturbance, examining resistance, recovery, and structural adjustment beyond simple post-shock dynamics. The analysis tests whether regional adaptation capacity affected resistance and recovery by comparing regional and national gross value added (GVA) trajectories. Using GVA at constant 2019 prices for (2005–2019), the study defines reference (2005–2007) and performance (2008–2019) periods, computes cumulative GVA changes, constructs resilience indices (α_{ij} and β_{ij}) based on regional changes relative to national change, and measures economic re-orientation via a modified Finger–Kreinin Index for sectoral GVA shares. Pre-crisis, most regions showed positive GVA changes (North Aegean highest at +10.72%), while Western Macedonia and Central Greece declined. Post-crisis, all regions contracted with Greece at (−24.6%); Peloponnese decreased least (−18.9%) and Western Greece most (−29.5%), with regions showing distinct sub-intervals of contraction, stagnation, and modest growth after 2016. Only activities G–I showed minor share gains for Attica and Central Macedonia, indicating weak adaptive resilience. The resilience indices displayed varied performance, showing a positive α_{ij} when regional declines were less severe than the national average, and a positive β_{ij} for regions such as the South Aegean and Crete. However, the overall GVA losses categorized these regions as non-resilient. Structural re-orientation varied significantly: Attica showed strongest change (FKI 12.41), followed by Central Macedonia (3.57), while island regions showed low FKI values (≈0.38 – 1.17). Despite some relative resilience, Greek regions failed to develop broad adaptive capacity post-shock, highlighting the need for diversification policies beyond tourism-dependent models.*

Keywords: *adaptive regional resilience, economic crisis, reorientation, simple resilience index, F-K index, NutsII regions.*
JEL classification: *R11 Regional Economic Activity Growth, Development, Environmental Issues, and Changes.*

1. Introduction

This study evaluates the economic resilience of Greek regions by analyzing changes in regional gross value-added (GVA) during the (2007-2009) economic disturbance. It constructs a resilience index

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based on these data and uses the Finger-Kreinin index to estimate regional re-orientation. Regional resilience was assessed by comparing the conditions before and after the disturbance, or by evaluating the initial and final states. Methodologically, this involves statistical indices, techniques, models, regional analysis, and econometric models.

The literature identifies three main categories of resilience: engineering, ecological, and adaptive resilience. The engineering approach focuses on how quickly a region returns to its original state after a disturbance without significant changes or collapse (McGlade et al., 2006).

Ecological resilience refers to a region's ability to reach a new level of economic performance without undergoing structural reorganization and functional adaptations and/or changes (Hill et al., 2008).

Adaptive resilience pertains to the capacity of a region to reorganize its operations, redefine development objectives, and reconfigure infrastructure to maintain its desired growth trajectory despite disturbances (Martin, 2012). In other words, it is defined as the ability of the regional economy to undergo structural, functional, and organizational changes to absorb shocks and recover, while maintaining or enhancing core performance. This involves reconfiguring firms, industries, technologies, and institutions to ensure sustained growth in output, employment, and wealth over time (Martin & Sunley, 2015; Martin, 2012).

The study of resilience encompasses various aspects such as risk, shock, resistance, recovery, and adaptability. These factors are essential for understanding resilience in specific regional contexts (Martin & Sunley, 2020). The Gross Value Added (GVA) variable is utilized to formulate a resilience index, which is then used to evaluate the resilience of Greek regions in response to the economic shock of 2007. The reliability of the index is assessed by comparing numerical results with the empirical evaluation of Greek regions based on percentage (%) changes in Gross Value Added (GVA) before and after the (2007-2009) financial crisis. Subsequently, an analysis is conducted to examine the contribution of regional restructuring to empirical research, focusing on the role of economic re-orientation in regional economic resilience.

This research will empirically investigate whether regional adaptation capacities affect the resistance and recovery performance of Greek regions at the NUTS II level. The structure of the paper is as follows. Section 2 reviews the literature, and Section 3 outlines the research methodology. Section 4 presents the results of assessing the resilience of Greek regions, and Section 5 offers conclusions and critical comments. The work ends with Section 6 and references.

2. Literature review

Academics and experts have dedicated their research to regional resilience since the concept has received significant attention in recent years. Existing research on regional resilience assesses the impacts of economic, social, and political factors. Crisis resilience cannot be reduced to post-shock returns to its original status because regions must demonstrate capabilities for structural change and adaptation to emerging situations (Martin & Sunley, 2015). The ability of regions to handle external and internal shocks is evaluated through quantitative GVA, productivity, and GDP metrics.

The resilience of an economic system is directly linked to strength, along with human capital management, productive activities, and local government capacity to create positive developmental situations (Bristow & Healy, 2014). Some authors have recognized economic flexibility with production diversity and entrepreneur reform as essential elements for enhancing regional adaptability (Martin & Sunley, 2015).

Various statistical approaches combined with econometric modeling systems enable the evaluation of regional resilience through the analysis of enabling factors alongside limiting elements within recovery processes (Rodríguez-Pose, 2017). Multiple approaches to assessing regional resilience employ basic statistical indices and complicated statistical indices, together with empirical measurements and econometric modeling.

Methodological approaches to regional economy assessment display benefits and difficulties because regional economies behave as interconnected systems that combine companies with workers and

governmental and private institutions. The observed variations in regional resilience depend on how each subsystem interacts with the outside environment because such connections shape how disturbances are handled through local constraints alongside available resources. This study empirically evaluates the resilience of Greek regions by analyzing changes in gross value-added (GVA) before and after a specified economic disturbance.

The financial crisis, which began in the United States in 2007 and became global in nature, ended a long period of economic growth, spread throughout the world and inevitably affected the Greek economy from 2008 onwards. The Greek economy in the period (1990-2007) showed rather satisfactory growth rates, which can be attributed to increased consumer spending and public investment in infrastructure projects with a view to hosting the Olympic Games in 2004 (Tsoulfidis, 2009). The global Financial Crisis that began in 2007 ended Greece's long stretch of economic growth and affected its economy from 2008. Between 1990 and 2007, Greece experienced solid growth driven by consumer spending and public investment, especially in preparation for the 2004 Olympics (Tsoulfidis, 2009).

The crisis in Greece started in August 2007 (Papastamou, 2011), leading to economic contraction, high unemployment, declining investments, stagnating real profits, and growing debt servicing challenges. Public debt in Greece rose sharply, reaching 127% of GDP in 2009 and 148% in 2010 (Sakipis, 2019; Papanikos, 2014). In 2008, Greece's consumption exceeded its production by 14% of GDP, and by 2011, imports were €21 billion higher than exports (Xafa, 2017; Sakipis, 2019). Dependent on foreign borrowing, Greece faced a dual challenge: the global financial crisis and the need for restrictive fiscal policies.

Within the context of this research, the reference period is defined as (2005–2007), and the performance period is defined as (2008–2019). During the performance period, intermediate reaction intervals (resistance and recovery) were recorded to assess the responses of the various regions to the shock.

A simple resilience index was constructed using GVA data. The reliability of the resilience assessments was examined by comparing resilience indices before and after the 2007 shock.

The empirical methodology follows previous studies that measured resilience using simple indices based on changes in GVA.

Notably, Lagravinese (2015) was among the first to incorporate a simple resilience index, analyzing Italian regions between 1970 and 2011 in response to economic recessions. Following Martin's (2012) interpretation of resilience, Lagravinese (2015) further decomposed resilience into two subcomponents, resistance and recovery, both based on employment changes relative to national trends. Subsequent studies have expanded this approach by employing resilience indices to measure regional economic adaptability across Europe. For example, (Giannakis and Bruggeman, 2019) utilized a simple regional resilience index to compare GVA changes at both the European Union (EU27) and national levels. Further empirical investigations have employed resilience indices to assess regional economic performance post-disturbance (Cainelli, Ganau, & Modica, 2019; Ezcurra & Rios, 2020; Oprea et al., 2020; Martin et al., 2016); Banica et al., 2020; Evenhuis, 2017; Wang & Li, 2022).

Alternative methodological approaches compare actual GVA changes to expected values over a specified period (Martin et al. 2016; Angulo, Mur, & Trívez, 2018). To measure resistance and recovery, indices such as "Resist" and "Recovr" are employed (Martin et al., 2016). Additionally, a regional resilience index for 255 NUTS II regions in EU27 countries between 2008 and 2013 was calculated, using regional GVA as a key variable (Angulo, Mur, and Trívez, 2018). The relationship between measured resilience and governance quality was also examined using the European Quality of Government Index (EQGI) via linear regression modeling (Ezcurra & Rios, 2020). Further research has developed resistance and recovery indices for the 2008 financial crisis using GDP data at both the regional and European levels (Oprea et al., 2020).

Methodological advancements in resilience calculations include the use of GVA in regions within the country (Cainelli, Ganau, & Modica, 2019). Empirical studies have consistently indicated correlations between regional resilience and sectoral or productive specialization. Regions with high levels of specialization in a particular industry tend to experience greater challenges in coping with economic crises

than those with more diversified economies. To assess adaptive capacity, researchers have developed indices based on the structural shifts in regional GVA.

This study modifies the Finger-Kreinin index-originally proposed for employment shifts-to measure shifts in regional GVA (Ženka, Pavlík & Slach, 2017; Kuliš, Šimundić, & Kuliš, 2022). The formula applied is $FKI_{t1,t2} = 0.5 \cdot \sum |GVAk_{t1} - GVAk_{t2}|$, where GVAk represents the share of GVA in industry k in total GVA of the region (according to NACE Rev.2), t_1 and t_2 index two points in time {t_1 indicates values for the years 2008, 2009…2019, while t_2 corresponds to the year 2007 (pre-crisis year)} (Finger & Kreinin, 1979; Ženka, Pavlík, & Slach, 2017).

By applying these empirical approaches, this study contributes to a broader understanding of regional resilience dynamics, offering valuable insights into policy measures aimed at fostering economic adaptability in the face of economic shocks. Future research should explore additional indicators beyond GVA to further refine resilience assessment methodologies.

3. Research methodological framework

This study adopts a comparative analysis of Greek regions during the Greek depth crisis of (2007-2009) as its methodological foundation. The primary variable utilized is the change in regional gross value-added (GVA), which serves as an index of the strength and stability of the local economy. The construction of the resilience index entails the utilization of regional gross value-added (GVA) data in a reference period (2005-2007) before and a performance period (2008-2019) after the economic shock, and the subsequent creation of three resilience indices.

These indices facilitate the comparison of regional changes with the corresponding national changes, or with the expected value that each region would have had if the disturbance had not occurred. Thus, the indices assess each region's ability to recover from an economic shock and return to a growth trajectory. The indices were then evaluated using an empirical quantitative method of calculating the percentage (%) change in Gross Value Added (GVA) in the reference and performance periods for the Greek regions.

Subsequently, an analysis is conducted to examine the contribution of regional restructuring to empirical research, focusing on the role of economic re-orientation in regional economic resilience. This study empirically investigated whether regional adaptation capacities affect the resistance and recovery performance of Greek regions at the NUTS II level.

The methodology includes the following stages:

[1] Collection of data on regional gross value-added (GVA) (in millions of euros at constant prices in 2019) during the examination (2005-2019) period.

[2] Calculation of the percentage change in gross value-added (GVA) before and after the 2007 shock.

[3] Creation of resilience indices based on changes in Gross Value Added (GVA) before and after the 2007 shock.

[4] Calculation of Finger-Kreinin Index and evaluation of possible regional re-orientation at the NutsII level.

[5] Comparative evaluation and analysis of the empirical assessment, Resilience and the KFI indices of the regions results.

4. Research results and comments

The empirical assessment of regional resilience with regard to changes in the total Gross Value Added (GVA) in the reference period (2005-2007) for Greek regions showed a positive change (except for the Ionian Islands) with different years of occurrence of its maximum value. Eleven (11) out of thirteen (13) regions showed a positive change in total GVA.

There was variation among regions in the year the maximum value of the variable occurred. Seven (7) regions, namely Attica, North Aegean, South Aegean, Crete, Eastern Macedonia-Thrace, Central Macedonia, and the Ionian Islands, showed the maximum value of total GVA in 2008. The largest percentage of positive change was recorded in the North Aegean (10.72%) and the smallest in the Ionian Islands (5.20%).

Four (4) regions show the maximum value of the variable in 2007: Epirus, Thessaly, Western Greece, and Peloponnese, with the largest positive change being the Peloponnese (7.48%) and the smallest positive change being the Epirus region (2.30%). The regions of Western Macedonia and Central Greece show the maximum value of GVA in 2005, with negative percentage changes in the period 2005-07. The largest percentage of negative change was recorded in Western Macedonia (-3.95%) and the smallest in Central Greece (-0.40%) according to Table 1.

Table 1. Cumulative percentage changes in total gross value added (GVA) in the reference and performance periods by region

GVA Change (%)	GR	Attiki	North Aegean	South Aegean	Crete	East Mace-donia - Thrace	Central Mace-donia	West Mace donia	Epirus	Thessaly	Ionia Islands	West Greece	Central Greece	Pelopo-nnese
2005-06	4.3	5.8	3.7	2.8	3.4	-1.3	4.8	-1.3	1.2	4.6	1.5	5.2	-0.9	4.1
2005-07	7.2	9.4	8.5	5.9	4.2	3.9	9.1	-4.0	2.3	5.5	3.8	6.2	-0.4	7.5
2005-08	7.1	9.4	10.7	8.3	5.5	5.9	9.2	-11.1	0.7	5.0	5.2	3.0	-1.5	6.5
2008-11														
2008-12				-28.1	-28.4			-0.2						
2008-13	-26.1		-27.4						-23.3	-27.1	-32.4			
2008-14							-29.0						-26.4	-22.0
20XX-15														
20XX-16	-1.8	-28.5		0.01	2.4		1.3			0.1	-0.2			1.2
20XX-17			-4.3			-27.7			-3.4			-32.9		
20XX-18														0.8
20XX-19	4.0	4.9	3.1	7.5	6.4	1.2	4.2	-24.8	1.5	4.6	5.6	1.9	6.5	1.9
2008-19	-24.6	-25.0	-28.3	-22.7	-22.0	-26.9	-25.1	-19.0	-23.6	-23.7	-28.7	-29.5	-21.6	-18.9

Note: The "X" in the year numbering represents the final year of the measured value
Source: own processing.

For the post-crisis period 2008-19 (performance period), according to Table 1, the GVA for Greece showed a significant negative change (-24.6%), as well as for Attica (-25.0%), North Aegean (-28.3%), South Aegean (-22.7%), Crete (-26.9%), Eastern Macedonia-Thrace (-26.9%), Western Macedonia (-19%), Epirus (-23.6%), Thessaly (-23.7%), Ionian Islands (-28.7%), Western Greece (-29.5%), Central Greece (-21.6%), and Peloponnese (-18.9%). The best reaction for the performance period is recorded by the Peloponnese region and the worst by the Western Greek region.

Another characteristic of the reaction of the country's regions in the period 2008-19 is the existence of intermediate distinct intervals of change, which for Greece were the 2008-13 period with a decrease (-26.15%), the 2013-16 period with a decrease (-1.8%) and the 2016-19 period with an increase (+4.0%).

In terms of the number of intermediate intervals in the performance period, similar behavior to the country, that is, with the negative overall contraction of GVA in the period 2008-19 comprising three (3) intermediate stages of changes (consisting of a first period of significant reduction in GVA and two more of a much smaller negative or (marginally) positive change), the regions of North Aegean, South Aegean, Crete, Central Macedonia, Epirus, Thessaly, and Ionian Islands. The Peloponnese presents four (4)

intermediate distinct intervals of change: the regions of Attica, Eastern Macedonia-Thrace, Western Greece, and Central Greece that show two (2) intermediate intervals of change (the first with negative and the second with positive change), while Western Macedonia is constantly shrinking until 2019 (except for the period 2008-12 when the Western Macedonia shows marginally zero change).

More specifically, for the seven (7) regions that exhibit similar behavior to the country, the intermediate intervals of change are as follows:

1. For the North Aegean, in the first 2008-2013 period with a decrease (-27.4%), in the 2013-2017 period with a decrease (-4.30%) and in the 2017-2019 period with an increase (+3.1%);
2. For the South Aegean, in the 2008-2012 period with a decrease (-28.05%), in 2012-2016 period with a marginal increase (+0.01%) and in 2016-2019 with an increase (+7.5%);
3. Crete with the period of contraction 2008-2012 (-28.4%), the 2012-2016 period with an increase (+2.4%) and 2016-2019 with (+6.45%);
4. Central Macedonia, with a contraction period in 2008-14 (-29.04%), growth in 2014-2016 with (+1.28%) and 2016-2019 with (+4.2%);
5. The region of Epirus with the contraction intervals 2008-2013 (-23.3%) and 2013-2017 (-3.4%) and the period of growth 2017-2019 (+1.54%);
6. Thessaly with the contraction period 2008-2013 (-27.1%), the growth intervals 2013-2016 (+0.08%) and the 2016-2019 period (+4.6%);
7. The Ionian Islands with contraction intervals 2008-2013 with (-32.4%) and 2013-16 with (-0.25%) and the growth period 2016-19 with (+5.6%).

   The situation in other regions is as following:

   - for the Attica region, the individual periods refer to 2008-2016 with a decrease (-28.5%) and 2016-2019 with an increase (+4.9%);
   - for Eastern Macedonia-Thrace with a decrease of 2008-2017 with a decrease and in the 2017-2019 period with a (+1.2%) increase;
   - for Western Greece, the period of contraction 2008-2017 with (-32.9%) and growth in 2017-2019 with (+1.9%);
   - for Central Greece with the 2008-2014 period with a decrease (-26.4%) and 2014-2019 with an increase (+6.5%);
   - and for the Peloponnese with the 2008-2014 with a decrease (-22.0%), 2014-2016 with an increase (+1.2%) and 2016-2019 with an increase (+1.9%).

Trying to interpret the reactions of regions through adaptive resilience, taking into account on the one hand the new equilibrium situation in which they move, on the other hand, their efforts to continuously adapt after the imposition of the 2007 shock, we conclude the following: this adaptive process is "highlighted" by the continuous changes/fluctuations in GVA prices in the period after the imposition of the disturbance and the specialization they are trying to acquire in specific sectors of economic activity.

From the examination of the regions and Greece, we find that only for one (1) category of economic activity, namely in the sectors [G, H, I: Wholesale and Retail Trade, Repair of Motor Vehicles and Motorcycles/ Transport and Storage/Accommodation and Food Service Activities], the regions of Attica and Central Macedonia (and Greece) seem to achieve a small increase in their shares in the national GVA. In the other nine sectors of economic activity, no region seems to differentiate and specialize in their behavior after the 2007 shock; that is, they operate under a continuous adaptation of their operations, organizational structure, and systems to respond to the effects caused by the disruption of 2007. Therefore, adaptive resilience does not seem to interpret the “adaptive” approach for Greek regions.

Continuing the research and to "construct" simple resilience indices, we applied two (2) different methodological approaches according to the literature, using α_{ij} and β_{ij} indices Table 2.

Table 2. (Simple) regional resilience indices: relationships and calculation formulas

Resilience Index	
$\alpha_{ij}=\frac{X_\alpha - X_\beta}{\lvert X_\beta \rvert}$	$\beta_{ij}=\frac{X_\alpha - X_\beta}{\lvert X_\beta \rvert}$
$X_\alpha=\Delta J_i$ i.e. the change in variable J of region i in the time interval [t -1, t] $X_\beta=\Delta J_n$ i.e. the change in variable J in the country in the time interval [t -1, t]	$X_\alpha=g_i$ i.e. the rate of change of the variable J of region i in the time interval [t -1, t] $X_\beta=g_n$ i.e. the rate of change of variable J in the country in the time interval [t -1, t]

Source: own processing.

Each index is calculated for the reference and performance intervals and the Gross Value Added (GVA) variable [taking into account the relevant resilience indices for the intermediate resistance and recovery intervals of the performance period].

Table 3a displays the outcomes of applying a_{ij} resilience index to the Gross Value Added (GVA) for each region throughout the entire study period (2005-2019), as well as for the intervals before and after the 2007 shock.

Table 3a. Resilience index α_{ij} for GVA by region for reference and performance periods.

GVA TOTAL	a_{ij} 2007-2005	a_{ij} 1st Sub-Period	a_{ij} 2nd Sub-Period	a_{ij} 3rd Sub-Period	a_{ij} 2019-2008
Attica	-0.39	0.47	2.26		0.81
North Aegean	-0.98	0.98	0.97	-0.99	1.02
South Aegean	-0.97	0.96	1.00	-0.94	1.22
Crete	-0.97	0.95	1.06	-0.92	1.03
East Macedonia-Thrace	-0.98	0.96	1.03		0.94
Central Macedonia	-0.83	0.85	1.09	-0.86	0.64
Western Macedonia	-1.01	1.00	0.73		0.90
Epirus	-0.99	0.98	0.96	-0.99	0.92
Thessaly	-0.96	0.95	1.00	-0.94	0.85
Ionian Islands	-0.99	0.98	1.00	-0.98	1.02
Western Greece	-0.96	0.94	1.05		0.76
Central Greece	-1.00	0.95	1.16		0.92
Peloponnese	-0.96	0.96	1.03	-0.97	0.99

Source: own processing.

A brief analysis of these results is provided in Table 3b.

Table 3b. Resilience index α_{ij} for Gross Value Added (GVA) by region for reference and performance periods

Region	2005–2007 (Reference Period)	2008–2019 (Performance Period)	2008–2019 Overall
Attica	Negative (growth < national)	2008–2016: Positive 2016–2019: Negative	Positive
North Aegean	Negative	2008–2013: Positive 2013–2017: Positive 2017–2019: Negative	Positive, post-2007 loss slightly exceeded pre-2007 gains
South Aegean	Negative	2008–2012: Positive 2012–2016: Positive 2016–2019: Negative	Positive, post-2007 loss < pre-2007 gain
Crete	Negative	2008–2012: Positive 2014–2016: Positive	Positive, post-2007 loss < pre-2007 gain

Region	2005–2007 (Reference Period)	2008–2019 (Performance Period)	2008–2019 Overall
		2016–2019: Negative	
Eastern Macedonia–Thrace	Negative	2008–2017: Positive 2017–2019: Positive	Positive, post-2007 loss < pre-2007 gain
Central Macedonia	Negative	2008–2014: Positive 2014–2016: Positive 2016–2019: Negative	Positive, post-2007 loss < pre-2007 gain
Western Macedonia	Negative (Regional decline, national growth)	2008–2011: Positive 2011–2019: Positive	Positive, post-2007 loss > pre-2007 loss
Epirus	Negative	2008–2013: Positive 2013–2017: Positive 2017–2019: Negative	Positive, post-2007 loss < pre-2007 gain
Thessaly	Negative	2008–2013: Positive 2013–2016: Positive 2016–2019: Negative	Positive, post-2007 loss < pre-2007 gain
Ionian Islands	Negative	2008–2013: Positive 2013–2016: Positive 2016–2019: Negative	Positive, post-2007 loss < pre-2007 gain
Western Greece	Negative (employment growth < national)	2008–2017: Positive 2017–2019: Positive	Positive, post-2007 loss < pre-2007 gain
Central Greece	Negative (GVA declined, but < national decline)	2008–2014: Positive 2014–2019: Positive	Positive, post-2007 loss > pre-2007 loss
Peloponnese	Negative	2008–2014: Positive 2014–2016: Positive 2016–2019: Negative	Positive, post-2007 loss < pre-2007 gain

Source: own processing.

With regard to the resilience index α_{ij}, while most regions displayed post-2007 economic resilience by weathering downturns better than the national average, the initial weaknesses before the depth crisis and varied recovery strengths highlight the structural disparities in regional economies.

The resilience index b_{ij} for Gross Value Added (GVA) by each region is shown in Table 4a. This covers the whole period from 2005 to 2019, as well as the times before and after the 2007 shock.

Table 4a. Resilience index β_{ij} for GVA by region for reference and performance periods.

GVA TOTAL	β_{ij} 2007-2005	β_{ij} 1st Sub-Period	β_{ij} 2nd Sub-Period	β_{ij} 3rd Sub-Period	β_{ij} 2019-2008
Attica	-0.37	-0.16	1.57	-0.12	0.50
North Aegean	-0.30	0.48	3.29	-0.27	1.99
South Aegean	1.02	0.38	46.60		8.16
Crete	-0.15	0.19	-0.58	2.85	1.47
East Macedonia-Thrace	0.75	0.42	-1.85	-0.57	-0.28
Central Macedonia	0.69	-0.28	1.20	2.66	-1.16
Western Macedonia	1.18	-0.11	1.33	-0.76	-3.55
Epirus	0.68	0.28	-4.10	-0.76	-1.86
Thessaly	-0.55	0.13	-5.45	1.76	-1.32

GVA TOTAL	β_{ij} 2007-2005	β_{ij} 1st Sub-Period	β_{ij} 2nd Sub-Period	β_{ij} 3rd Sub-Period	β_{ij} 2019-2008
Ionian Islands	-1.22	0.29	-2.69	3.19	1.92
Western Greece	1.06	-0.13	-3.18	-0.12	-3.18
Central Greece	-0.20	0.07	1.16	1.32	-0.70
Peloponnese	-1.11	0.36	1.19	1.19	0.84

Source: own processing.

A brief analysis of this data is given in Table 4b.

Table 4b. Resilience index β_{ij} for Gross Value Added (GVA) by region for reference and performance periods

Region	2005–2007 (Reference Period)	2008–2019 (Performance Period)	2008–2019 Overall
Attica	Positive (GVA > national)	2008–2016: Negative 2016–2019: Positive	Negative (more decline than national)
North Aegean	Positive	2008–2013: Negative 2013–2017: Negative 2017–2019: Positive	Negative
South Aegean	Negative	2008–2012: Negative 2012–2016: Positive 2016–2019: Positive	Positive (less decline than national)
Crete	Negative	2008–2012: Negative 2012–2016: Positive 2016–2019: Positive	Positive
Eastern Macedonia -Thrace	Negative	2008–2017: Negative 2017–2019: Positive	Negative
Central Macedonia	Positive	2008–2014: Negative 2014–2016: Positive 2016–2019: Positive	Negative
Epirus	Negative	2008–2013: Positive 2013–2017: Negative 2017–2019: Negative	Positive
Thessaly	Negative	2008–2013: Negative 2013–2016: Positive 2016–2019: Positive	Positive
Ionian Islands	Negative	2008–2012: Negative 2012–2016: Positive 2016–2019: Positive	Negative
Western Greece	Negative	2008–2017: Negative 2017–2019: Positive	Negative
Central Greece	Negative	2008–2017: Negative 2017–2019: Positive	Positive
Peloponnese	Positive	2008–2014: Positive 2014–2016: Positive 2016–2019: Negative	Mixed performance

Source: own processing.

Regarding the resilience index β_{ij}, many regions experienced sharper GVA declines than the national average (2008–2016), whereas several regions showed stronger GVA growth than the national average (2016–2019). Positive resilience was recorded in regions such as South Aegean, Crete, and Thessaly for (2008–2019) period.

The Finger-Kreinin Index (FKI) was used to study changes in trade or economic structures in Greek regions. It showed that regional economies were different. Some regions had big changes, while others had almost no changes in their economic activities from 2008 to 2019 (Table 5).

Table 5. Finger-Kreinin Index using GVA (average) for (2008-2019) period

NACE Class*	Attica	North Aegean	South Aegean	Crete	East Macedonia - Thrace	Central Macedonia	Western Macedonia	Epirus	Thessaly	Ionian islands	Western Greece	Central Greece	Peloponnese
A	0.37	0.08	0.18	0.84	0.48	0.77	0.20	0.8	0.32	0.08	0.65	0.37	0.31
B-E	12.58	0.04	0.16	0.11	0.71	4.80	1.55	0.42	1.96	0.21	2.26	2.26	1.11
F	22.14	0.69	1.32	2.99	1.89	8.13	1.10	1.57	3.09	0.98	2.85	4.25	0.59
G-I	20.87	1.76	3.74	2.72	2.94	8.22	0.92	1.61	3.71	2.89	3.73	4.83	2.66
J	11.29	0.16	0.20	0.43	0.32	0.98	0.14	0.16	0.38	0.13	0.53	1.34	0.45
K	4.43	0.04	0.10	0.15	0.20	0.72	0.07	0.10	0.17	0.05	0.25	0.57	0.22
L	9.17	0.23	0.58	0.72	0.92	2.02	0.19	0.35	0.64	0.34	0.74	1.45	0.83
M-N	16.20	0.14	0.13	0.70	0.68	2.51	0.20	0.22	0.82	0.12	0.39	2.01	0.51
O-Q	7.64	0.59	1.38	2.46	1.66	5.18	0.63	0.56	1.72	0.58	2.15	3.14	1.46
R-U	9.44	0.02	0.38	0.54	0.57	2.43	0.36	0.26	0.61	0.15	0.75	1.41	0.41
Total GVA	12.41	0.38	0.82	1.17	1.04	3.57	0.54	0.53	1.34	0.55	1.43	2.16	0.96

Source: own processing [*According to NACE rev. 2 A10 classification].

The key regional observations are summarized as follows: Attica region has higher values in the overall index (12.41), suggesting that its economy has undergone profound structural changes during the period (2008-2019).

The highest values appeared in sectors F (22,14), G-I (20,87) and O-Q (17,64). Central Macedonia exhibits the second highest importance performance with a total FK Index of 3.57, showing that the structure of its economy is partially structurally adjusted, such as Attica, and better adaptation compared to the rest of the country's regions. The highest values were observed for F(8.13) and G-I(8.22). Western Greece and Thessaly follow with an FKI of (1.43) and (1.34), respectively, showing a moderate similarity to other regions, with their highest values occurring in F, G-I, and R-U.

Island Regions (North and South Aegean, Ionian Islands, and Crete) have lower FKI values, with overall ratios of (0.38 – 1.17), reflecting their more specialized economy, mainly due to tourism. Western Macedonia and Epirus are the two regions that record low FKI (0.54 & 0.53 respectively). This indicates that they have less structural convergence with large economic regions.

Finally, Peloponnese and Central Greece presented an FKI of 0.96 and 2.16, respectively, which indicates that they have some building blocks in common with other areas but still retain peculiarities in their economy Figure 1.

5. Conclusions

Considering the variable of gross value-added (GVA) and its (%) changes for the reference and performance periods, the Greek regions are characterized as non-resilient because the negative changes (contractions) of the performance period outweighed any positive changes (growth) of the reference period. The interpretation of resilience through the adaptive approach considers a new equilibrium situation in which they move and their continuous adaptation efforts since the imposition of the 2007 disturbance.

From the examination of the results, Greek regions appear to differentiate and refine their behavior after the 2007 shock in only one (1) out of ten (10) sectors of economic activity (according to the NACE Rev.2 classification). That is, the effort to operate under a continuous adaptation of their operations to reorganize their structure and systems to respond to the effects caused by the disruption of 2007. Therefore, adaptive resilience does not seem to interpret the adaptive approach for Greek regions.

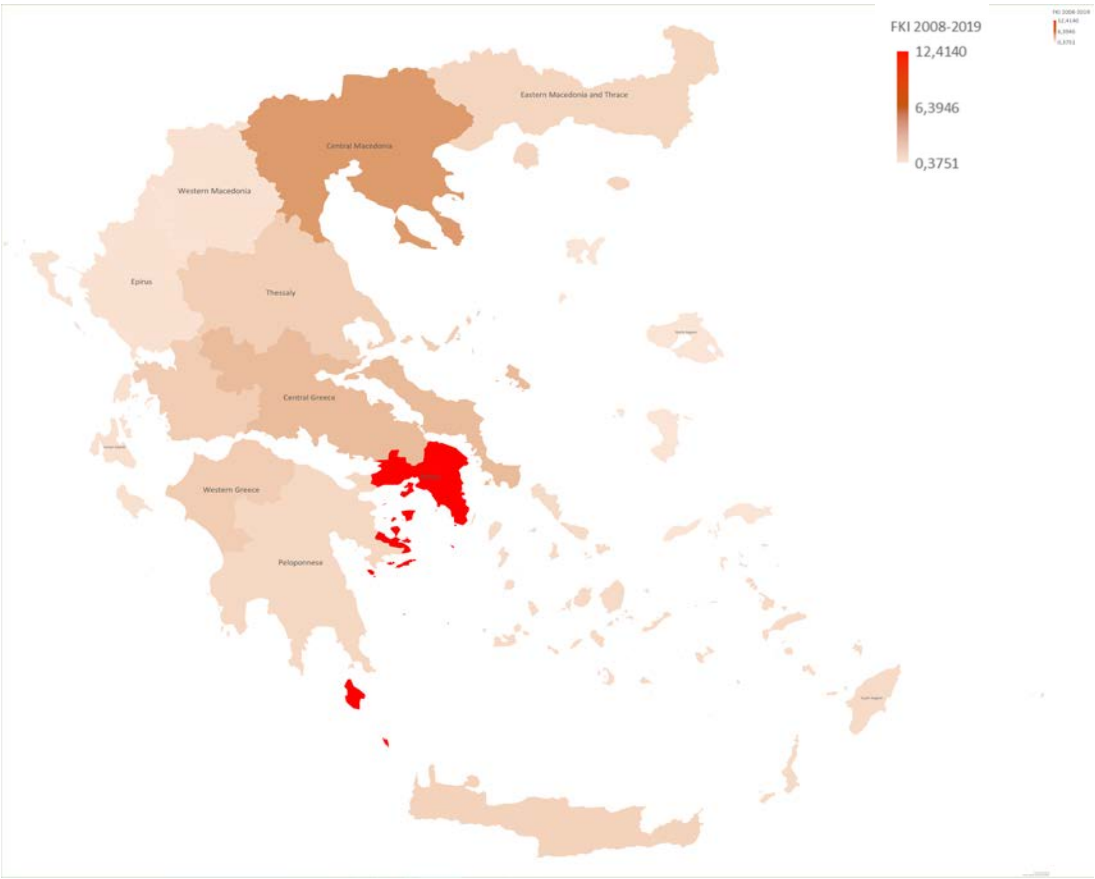
Regional resilience using Gross Value Added (GVA) resulted in the following: No region showed resilience in the (2008-2019) performance period. Peloponnese had the best performance with the smallest

decrease (-18.9%) in the 2008-19 performance period. Western Greece had the worst performance, with the largest decrease (-29.5%) in the (2008-2019) performance period. These regions moved to a lower level after the 2007 disruption. GVA showed 2-3 distinct intervals of change for most regions.

Regarding the main sectors of economic activity and their correlation with resilience, it is noted that for Sectors [G, H, I], we conclude that all regions had a peak value in 2008. Attica, Central Macedonia, South Aegean, and Crete had the smallest decreases in their intervals of change, following the pattern of total GVA.

For Sectors [O-Q], we have a peak value in 2009 (two years after disturbance) with significant growth for all regions except the Ionian Islands. Central Macedonia and Central Greece contributed significantly to these sectors. The changes followed the intervals of change in total GVA. For Sector [L], we have a peak value in 2010 (three years after disturbance), a smaller negative change between the three main sectors, and contractions of <10% for all regions by 2018.

Figure 1. Average Finger-Kreinin Index for Greek NUTSII regions for (2008-2019) period



Source: own processing using Microsoft OpenStreetMap.

In more specific conclusions, we observe that only in sectors [G, H, I], Attica and Central Macedonia managed a small increase in their shares. In the remaining nine sectors, no region showed significant differentiation or specialization after disruption. The analysis shows that regions have failed to develop adaptive resilience in most sectors and all are classified as non-resilient under the adaptive approach.

The evaluation of a_{ij} index focuses on the following results. For the reference period of (2005-2007), all regions showed a negative value for the index. This means that the positive changes in GVA were

smaller than national changes. A negative value of the index represents less resilience than the national value. For the performance period (2008-2019), the index shows a positive value, that is, the negative changes of the regions were smaller than the national ones, where some regions (Attica, Eastern Macedonia-Thrace, Western Macedonia, Central Greece) show positive values for all sub-intervals of the (2008-2019) performance period.

The β_{ij} index results in the following equation. For the reference period (2005-2007), the regions show different signs (positive or negative); some of them, such as Attica, North Aegean, and Central Macedonia, show positive values. A positive value of the index represents greater resilience than the rest of the region. For the performance Period of (2008-2019), the index shows a positive value for some regions, such as South Aegean, Crete, Western Macedonia, Epirus, Thessaly, Central Greece, and Peloponnese. Western Macedonia, Epirus, and Peloponnese were the only regions that showed a positive index value for the first subperiod of the performance period.

With regard to the Overall Conclusions for Finger-Kreinin Index, we summarize the following: Attica dominates the Finger-Kreinin index, compared to other regions, indicating strong structural changes in its economic structure during the period (2008-2019). Central Macedonia follows, indicating that its economy is approaching the structure of Attica, but with lower convergence. Islands and less developed regions have lower prices, which indicates that they maintain a different growth structure. Rural and regional economies show low structural convergence, with the regions of Western Macedonia and Epirus showing the lowest values of the indicator.

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