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UKRAINE'S SOCIO-ECONOMIC RESILIENCE IN THE FACE OF SHOCKS: SPATIAL AND TEMPORAL MODELING

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This paper aims to assess the socio-economic resilience of Ukraine's regions in the face of shocks, including the Russian Federation's invasion of Ukraine, territorial annexation, the 2014 socio-political crisis, and the 2020-2021 COVID-19 pandemic. The comprehensive methodological approach applied in this paper combines the construction of temporal and spatial composite indicators of the labor market, and social, demographic, and economic development, with the identification of shock-related losses, the recovery capacity, and the dynamics of vulnerability and recovery. The framework distinguishes between immediate losses and the long-term adaptive capacity. The empirical results show that the two major shocks (the 2014 crisis and the 2020-2021 COVID-19 pandemic) caused significant regional losses, with the deepest labor market decline in Donetska Oblast and Luhanska Oblast and higher resilience in the western and central regions. Vulnerability lasted for two to three years, while recovery exceeded four years. Overall, resilience depends not only on overcoming immediate shocks but also on strengthening demographic stability, the institutional capacity, and adaptive mechanisms to ensure sustainable postwar recovery.

Keywords: resilience, Ukraine, shocks, labor market, demographic situation, recovery

JEL Classification: O15, O20, R33

INTRODUCTION

The socio-economic resilience of regions is an existential determinant of their development, reflecting the ability of systems to respond effectively to external challenges, adapt to environmental changes, and restore stability after the impact of adverse factors. This capacity requires the creation of mechanisms for rapid adaptation, the mobilization of resources, and their effective use to mitigate potential risks and threats, including migration. An important feature of Ukraine's socio-economic resilience in wartime conditions is the integration of economic development with the elements of migration security, which involves not only preventing the negative consequences of migration processes but also creating conditions for their effective management. Such integration ensures a more balanced response to shocks and enhances regional adaptability to new realities.

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The synergy between resilience and adaptability strengthens the effectiveness of regional economic policies, which allows for not only the preservation of stability but also the creation of conditions for sustainable growth, improvements in living standards, and the development of social institutions. As a result, resilient regions are capable of maintaining long-term stability and competitiveness in the context of global change. However, the current challenges of Ukraine's socio-economic development (the post-2014 military aggression, migration, pandemics, and systemic destabilization) significantly complicate the implementation of the policies aimed at building resilience. These critical periods demand the rethinking of approaches to managing socio-economic processes, introducing the modern principles and tools that would ensure resilience as a key factor of sustainable progress. In this sense, resilience is not only a condition for recovery but also a new paradigm of economic growth, oriented towards a fair distribution of benefits, the financial self-sufficiency of regions, and the accumulation of a "safety margin" for future shocks.

The subject matter of this study is the socio-economic resilience of Ukrainian regions, defined as a systemic characteristic that determines their ability to withstand, adapt to, and recover from external shocks. Resilience is examined through the interrelation of the labor market dynamics, social and demographic factors, migration processes, and the efficiency of economic development. Particular attention is paid to the response of the regional systems to military aggression, forced migration, pandemics, and macroeconomic crises.

The purpose of the article is to substantiate the conceptual and methodological foundations for assessing socio-economic resilience, measure vulnerability and recovery dynamics under the influence of shocks and identify the key determinants that form the basis for sustainable regional development in Ukraine.

The research is based on the following hypotheses:

H1: Socio-economic resilience is determined both by the degree of economic losses during a shock and by the adaptability and recovery capacities in the post-shock period.

H2: Endogenous and exogenous environmental factors can act as both catalysts and regressors of resilience and economic development, shaping the projection of shock consequences.

The study applies the conceptual framework of resilience theory, integrating the economic, social, and demographic dimensions. Methodologically, resilience is assessed through the spatiotemporal composite indicators of the labor market development, social and demographic stability, and the efficiency of economic development. The calculations consider the depth, duration, and speed of vulnerability; the depth, duration, and speed of recovery; the safety margin; and the degrees of resistance, recovery from and adaptation to shocks. This approach distinguishes between the shock vector (economic losses and immediate vulnerability) and the shock consequence vector (the long-term recovery and adaptation capacity). The empirical basis consists of the regional statistical data for the period from 2010 to 2021, supplemented with projections for the wartime and postwar periods.

LITERATURE REVIEW

The concept of resilience has become one of the key categories in modern interdisciplinary research. Originally rooted in mechanics, physics, ecology, and psychology, the term later penetrated into the discourse of disaster studies, regional economics, and social sciences. The Latin root *resiliere* ("to jump back") highlights the essence of this category, which is not limited to notions of stability or resistance but emphasizes elasticity, flexibility, and the capacity for renewal after external shocks (Haustova & Reshetnyak, 2023). This understanding has allowed resilience to evolve into a cross-cutting concept that bridges natural and social sciences.

The concept of resilience has undergone a profound evolution from its origins in the natural sciences to its present role as a central category in socio-economic analysis. Initially, resilience was understood within mechanics and physics as the property of a material

to regain its original form after deformation. Later, in ecology, it came to denote the ability of ecosystems to withstand external shocks and maintain stability. In psychology, resilience was linked to the adaptive capacity of individuals in coping with stress and trauma, while in disaster studies it became a critical concept in understanding community responses to natural hazards and extreme events. This interdisciplinary foundation paved the way for transferring the category into the field of economics and social sciences, where resilience began to describe the ability of economic and social systems to adapt to shocks, crises, and long-term structural transformations (Jakopin, 2020). The growing frequency and intensity of crises (financial downturns, pandemics, military conflicts, migration surges (Semiv, Berezivskiy, Baranyak, Mulska & Ivaniuk, 2021), and climate change) stimulated the expansion of the concept, making it a key analytical tool for explaining both the vulnerabilities of socio-economic systems and their adaptive strengths.

In the context of regional economics, resilience reflects the capacity of territories to anticipate, withstand, and recover from shocks without compromising long-term development prospects. This implies not only the "bounce-back" to pre-crisis trajectories but also the potential for positive transformation, the diversification of structures, the upgrading of institutions, and the acceleration of innovation. The transition of resilience from a natural science to a socio-economic category has therefore enriched it with multidimensional content, making it simultaneously a theoretical framework, a practical policy tool, and a methodological challenge.

The UN Office for Disaster Risk Reduction defines it as the ability of systems, communities, and societies exposed to hazards to resist, absorb, accommodate, adapt to, transform, and recover from their impacts (United Nations Office for Disaster Risk Reduction, 2017). This broad formulation reflects resilience not only as survival but also as transformation in the face of risks. Similarly, A. Mitchell (2013) highlights resilience as the capacity of households, communities, and nations to absorb shocks while positively adapting and reorganizing livelihoods under long-term pressures. From an economic perspective, resilience is increasingly understood not only as recovery but as anticipation, preparation, and the ability to sustain development even under persistent disruptions. K. A. Foster (2007) stresses this anticipatory dimension, defining regional resilience as the ability to anticipate, prepare for, respond to, and recover from disturbances.

Scholars have further refined these interpretations. J. Fiksel (2006) describes resilience as the ability of a system to survive, adapt, and evolve in the face of uncertainty. O. Novikova and Y. Ostafychuk (2023) stress its practical importance: by embedding resilience mechanisms, institutions and societies can remain viable and effective in complex crisis environments, reducing long-term losses.

This conceptual evolution has laid the foundation for applying resilience to socio-economic systems. Fundamental studies (Simmie & Martin, 2010; Martin, 2012; Carriere, 2016; Levytska, Mulska, Shushkova, Ivaniuk, Vasyltsiv, Krupin & Ivanova, 2022; Melnyk, Ivaniuk, Leshchukh & Halkiv, 2023) focus on the theoretical underpinnings of socio-economic resilience, analyzing its drivers, mechanisms, and institutional frameworks. Empirical studies test these theories under specific shocks: financial and economic crises (Doran & Fingleton, 2016; Voznyak, Mulska, Bil, Patytska & Lysiak, 2022), the COVID-19 pandemic (Eshel, Kimhi & Marciano, 2020; Haldane, De Foo, Abdalla, Jung, Tan, Wu, Chua, Verma, Shrestha, Singh, Perez, Tan, Bartos, Mabuchi, Bonk, McNab, Werner, Panjabi, Nordström & Legido-Quigley, 2021; Melnyk, Leshchukh & Baranova, 2021), and wars or conflicts (Heyets, 2022; Vasyltsiv, Melnyk, Leshchukh, Fleychuk & Ilyash, 2024). Many thematic works also study resilience at the level of spatial or social systems, highlighting sectoral differences and vulnerabilities (Walker, Holling, Carpenter & Kinzig, 2004; Boorman, Fajgenbaum, Ferhani, Bhaskaran, Arnold & Kohli, 2013; Rizzi, Graziano & Dallara, 2018; Voznyak, Patytska, Mulska, Zherebylo & Sorokovyi, 2024).

Against this backdrop, methodological debates have emerged around how best to measure resilience. The

technical approach, most prominently represented by M. Friedman's *plucking model* (Friedman, 1993), interprets resilience as the ability of economies to return to potential growth trajectories after downturns (Shpak, Kulyniak, Novakivskyi & Oleksiv, 2023; Zhu, Ying & Xiang, 2025). This perspective equates resilience with recoverability: actual growth is assumed to converge with potential growth over time. Its limitation is a narrow, mechanical interpretation that overlooks adaptive or transformative capacities.

The ecological approach (Burlutska, 2016; Afolabi, Olanrewaju & Adekunle, 2022; Boiko, Lyzak, Vasyltsiv, Lupak & Ohinok, 2024) shifts the focus towards thresholds and phase transitions. Resilience is measured by the scale of shocks a system can absorb before shifting to a new state. This approach is valuable for highlighting structural transformation, but it tends to underplay recovery dynamics (Vasyltsiv, Mulska, Hrabynska, Ivaniuk & Shopska, 2023). A system that stabilizes after a decade-long recovery period may technically be defined as resilient, but in practice such a system exhibits low adaptability.

The expert approach, relying on composite indices constructed through subjective weighting, offers another perspective. M. Abdul-Rahman, W. Alade and S. Anwer (2023), for example, analyzed campus resilience in Nigeria using AI-based social media analysis and Delphi surveys. Although innovative, such methods are context-dependent, fragmented, and difficult to replicate. In addition to these dominant schools, other authors have attempted to broaden the measurement of resilience. E. Hill, H. Wial and H. Wolman (2008) distinguish between resilient, shock-resistant, and non-resilient systems, but offer no clear operational thresholds. M. Kahsai J. Yu, M. Middleton, P. V. Schaeffer and R. Jackson (2015) propose a territorial resilience index based on the six dimensions: industrial diversity, entrepreneurship, human and social capital (Halkiv, Karyy, Kulyniak, Kis & Adamovsky, 2022), infrastructure, and income diversity. J. Bruneckiene, I. Pekarskiene, O. Palekiene and Z. Simanaviciene (2019) introduce a more comprehensive approach, demonstrating that regional resilience in Lithuania depends on the ability to manage unplanned shocks at the national and international levels. Recent studies (Carriere, 2016; Mulska, Storonyanska, Patytska, Ivaniuk & Voznyak, 2023; D'Ambrosio & Migheli, 2025) integrate risk theory, spatiotemporal approaches, and labor market analysis, pointing towards the necessity of multidimensional resilience assessment.

This recognition has led to calls for more comprehensive methodologies. Scholars argue that resilience assessment must consider not only the fact of recovery but also the depth, duration, and speed of both vulnerability and recovery, the role of safety margins, and the balance between resistance, adaptability, and transformation. It is within this framework that the present study develops its authorial methodology. By distinguishing between the shock vector (immediate economic losses and vulnerability dynamics) and the shock consequence vector (the recovery capacity, the safety margin, and adaptation), the proposed approach integrates spatiotemporal indicators and provides a more balanced, policy-relevant tool for analyzing socio-economic resilience. This methodology addresses the weaknesses of the technical, ecological, and expert approaches, offering a framework capable of explaining both the short-term elasticity and long-term adaptive capacity of the Ukrainian regions under conditions of war, migration crises, pandemics, and global turbulence.

METHODOLOGY

To construct a series of empirical indicators of the socio-economic development of the Ukrainian regions within the spatiotemporal approach, the catalysts and regressors are normalized using Equation 1. Unlike classical normalization methods, this approach incorporates the threshold values specific to each indicator, region, and period. The key principle is not to maximize or minimize the observed values relative to the sample extremes, but rather to identify the deviation of each indicator from the predefined threshold:.

$$z_{it}^{n} == \begin{cases} \frac{x_{it}^{n}}{a_{iL}}, & a_{iL} \geq x_{max} \\ \frac{a_{iL}}{x_{it}^{n}}, & a_{iL} \leq x_{min} \end{cases}, \quad (1)$$

where z_{it}^{n} is the normalized value of the i component of the n region in the t period; x_{it}^{n} is the initial value of the i component of the n region in the t period; a_{iL} is the threshold value of the i indicator in the t period.

Therefore, Equation 1 applies threshold-based normalization, where the comparison is made against an economically meaningful benchmark (a_{iL}) instead of the minimum or maximum observed values. Such thresholds may represent policy targets, minimum acceptable standards, or maximum permissible constraints. The normalized value (z_{it}^{n}) reflects the extent to which the actual indicator deviates from this benchmark. The thresholds were established using a combined approach, drawing on statistical references (national averages, deviations) as well as the strategic policy documents in the areas of employment, social development, and economic resilience. This ensures the consistency of normalization across regions and time, while also capturing the dual character of the indicators: catalysts, for which exceeding the threshold reflects progress, and regressors, where exceeding the threshold signals increased vulnerability.

Equation 2 is used to construct the series of the empirical indicators of the socio-economic development of the regions in the component projection.

$$SED_{tn}^{k} = Mz_{it}{}^{n} \quad (2)$$

where SED_{tn}^{k} is the empirical value of the k component of the socio-economic development of the n region in the t period; M is the average value of the indicators in the component.

The composite indicator of the socio-economic development of the regions is calculated by the method of the geometric mean (Equation 3).

$$SED_{t}^{n} = \sqrt[j]{SED_{tn}^{k}}, \quad (3)$$

where SED_{t}^{n} is the empirical value of the composite indicator of the socio-economic development of the n region in the t period; j is the number of the components.

Given the multidimensional nature of resilience, an indicator of the socio-economic resilience of regions can be built by identifying the extent of economic losses as a result of a shock, the ability to recover, and dynamic estimates (period) of recovery and vulnerability. The level of resilience is the degree of change in the development indicator before, during, and after a shock.

A system of indicators is developed to assess socio-economic resilience (Equation 4):

$$sR_{t}^{n} = \left\{ \begin{matrix} VD_{t}^{n} \\ DD_{t}^{n} \\ SV_{t}^{n} \\ RD_{t}^{n} \\ RDu_{t}^{n} \\ SR_{t}^{n} \end{matrix} \middle| RSDT_{t}^{n} \right\} \quad (4)$$

where sR_{t}^{n} is the systemic indicator of the socio-economic resilience of the n region in the t period; VD_{t}^{n} is the depth of the vulnerability of the socio-economic system of the n region in the t period; DD_{t}^{n} is the period of the vulnerability of the socio-economic system of the n region in the t period; SV_{t}^{n} is the rate of the vulnerability of the socio-economic system of the n region in the t period; RD_{t}^{n} is the depth of the socio-economic recovery of the n region in the t period; RDu_{t}^{n} is the period of the socio-economic recovery of the n region in the t period; SR_{t}^{n} is the speed of the socio-economic recovery of the n region in the t period; $RSDT_{t}^{n}$ is the rate of the socio-economic resilience of the n region in the t period.

In this study, regional resilience is not considered as a one-dimensional value reduced to an integrated index, but rather as a multidimensional characteristic formed through a system of interrelated indicators. This approach makes it possible to capture the different aspects of resilience (for example, economic, social, and demographic) while avoiding the oversimplification of complex processes into a single aggregated measure. It also enables the identification of not only the overall level of resilience but also

of structural imbalances, "bottlenecks," or hidden development reserves that would remain invisible if only an integral index were used.

The depth of vulnerability (VD_t^n) is the degree or scale of the vulnerability of the socio-economic system, which reflects its losses under the influence of a shock (e.g. a decrease in productivity, efficiency, GRP, the percentage of the development index, etc.); it is estimated by Equation 5:

$$VD_t^n = \min_{t+l} SED_t^n - SED_l^n \quad (5)$$

where SED_i^n is the empirical indicator of the socio-economic development of the n region in the l period (shock period); $\min_{t+l} SED_t^n$ is the empirical indicator of the socio-economic development of the n region in the $t + l$ period (the vulnerability period).

The period of vulnerability (DD_t^n) is the period during which the socio-economic system incurs losses, is vulnerable to external influences or shocks, and is in a downward trend.

The speed of vulnerability (SV_t^n) is the rate or intensity at which a socio-economic system becomes vulnerable in response to external influences or shocks. It characterizes the degree of the loss of economic resilience and the pace of transition to a state of vulnerability as a result of threats:

$$SV_t^n = {VD_t^n}\Big/{DD_t^n} \quad (6)$$

The depth of recovery (RD_t^n) is the level or degree of the return of the pace of socio-economic development to the pre-shock trends. It shows how close the state of the socio-economic system in the $t+n$ period is to the state in the $t-n$ period:

$$RD_t^n = VD_t^n \sim VD_{t+l}^n \quad (7)$$

where VD^n_{t+l} is the depth of vulnerability in the $t+l$ period (the post-shock condition).

The period of recovery (RDu_t^n) is the period of time during which the socio-economic system is transformed into the pre-shock state. It is in an upward trend.

The speed of recovery (SR_t^n) is the pace or intensity at which the system restores its state of functioning and the dynamics of stable development. It characterizes the extent to which the socio-economic system returns to its previous state and how quickly it transitions to the state of resilience (Equation 8).

$$SR_t^n = {RD_t^n}\Big/{RDu_t^n} \quad (8)$$

The rate of resilience (RDu_t^n) is the ability of the system to remain less vulnerable and/or recover from an economic shock. It is calculated as the sum of vulnerability (ABC area) and recovery (CDE area):

$$RSDT_t^n = Vl_t^n + R_t^n \quad (9)$$

where Vl_t^n is the vulnerability of the n socio-economic system in the t period; is the recovery of the n socio-economic system in the t period.

RESULTS AND DISCUSSION

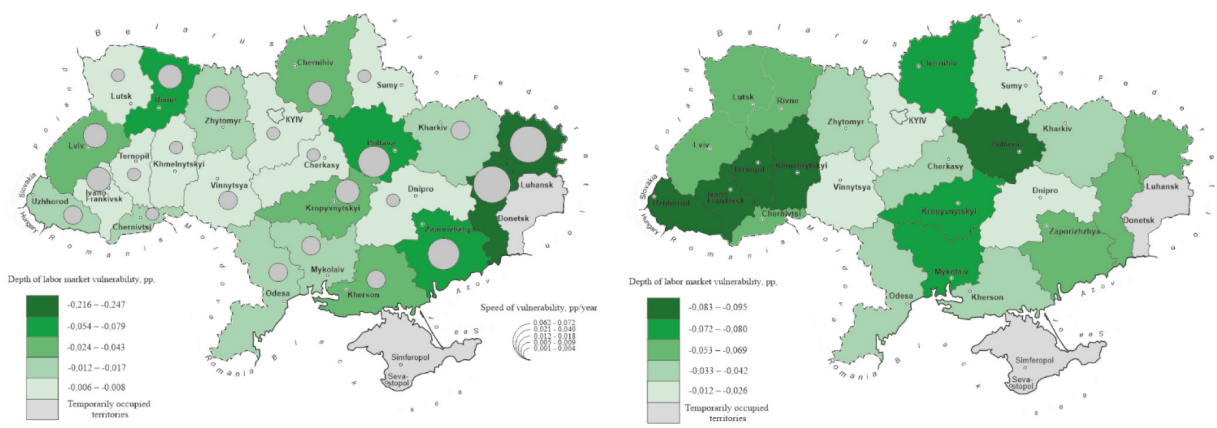
The socio-economic resilience of the regions is calculated by identifying the scale of the economic losses caused by shocks, the recovery capacity, and the duration of vulnerability and recovery. In the period from 2010 to 2014, the labor market development indicators at the national level declined by 6.4 pp. During this period, all regions experienced a decrease in the labor market performance, except Vinnytska (+2 pp), Volynska (+1.5 pp), Zhytomyrska (+2.2 pp), and Chernihivska (+3.5 pp) oblasts. In 2014, the lowest labor market development indicators were recorded in Luhanska (0.696) and Donetska (0.710) oblasts, reflecting the impact of military operations and the large-scale forced migration, including the formation of a new socially vulnerable group (IDPs). The downward trend in the regional labor markets persisted until the year 2016, with additional losses of 3-4 pp.

The empirical analysis of the regional labor market development in Ukraine during the period from 2010 to 2021 provides an analytical basis for assessing resilience through the indicators of vulnerability and recovery. The calculation results (Annex A) show

that the most severe labor market losses in the period between 2014 and 2015 were concentrated in Donetska and Luhanska oblasts (0.2 pp each), correlating with the intensity of hostilities, the economic collapse, and large IDP inflows. These factors not only reduced employment but also generated structural labor market distortions and new vulnerable worker groups. In contrast, Zaporizka (0.06 pp), Poltavska (0.08 pp), Khersonska (0.04 pp), and Lvivska (0.03 pp) oblasts experienced moderate losses due to more diversified economic structures and alternative employment opportunities.

During the COVID-19 pandemic, the labor market losses (0.05-0.1 pp) were observed across all oblasts, confirming the universal nature of this shock. Unlike the military conflict, the pandemic simultaneously affected all the regions, disrupting labor relations, reducing the labor potential, and constraining employment in both the industrial sector and the service sector. The crisis led to rising unemployment and declining labor force participation. Although unemployment decreased in the second quarter of 2021 amid economic recovery, it remained elevated due to structural mismatches, limited retraining incentives, and low labor mobility (Figure 1). Alongside official unemployment, hidden unemployment declined, which reflected in fewer part-time workers and inactive job seekers, while restrictions on external migration significantly influenced unemployment dynamics.

The identified asymmetry in the speed of the recovery of Ukraine's regional labor markets reflects a complex interaction between the depth of the shock, the sectoral structure of the economy, and the level of institutional adaptability. The regions that experienced minimal economic losses in 2014 (Mykolayivska, Khmelnytska, Cherkaska, Chernihivska, and Kharkivska oblasts) demonstrated shorter recovery periods due to the relatively small amplitude of the employment decline and the greater resilience of the local economic systems. The industrial regions proved to be more flexible, as they were able to restore the production processes and reallocate the resources more quickly, whereas service-dominated economies were more vulnerable due to their dependence on the population mobility and consumer demand. The COVID-19 pandemic highlighted the additional factors as follows: only a few oblasts (Dnipropetrovska, Zaporizka, Sumska, and Cherkaska) managed to adapt within one year, thanks to the relatively high levels of digitalization, the prevalence of remote work, and the available resources to sustain employment. At the same time, even in the most affected regions (Donetska and Luhanska oblasts), relatively high



a) 2014 b) 2021

Figure 1 The vulnerability of the regional labor markets: The spatial and dynamic approach, 2014, 2021

Source: Authors

recovery rates (0.05-0.06 pp per year) were recorded, which is partly explained by the mobilization capacity of the local economies and state support. However, the nationwide recovery rates remained low (0.01-0.02 pp per year), indicating structural constraints on the labor market adaptability.

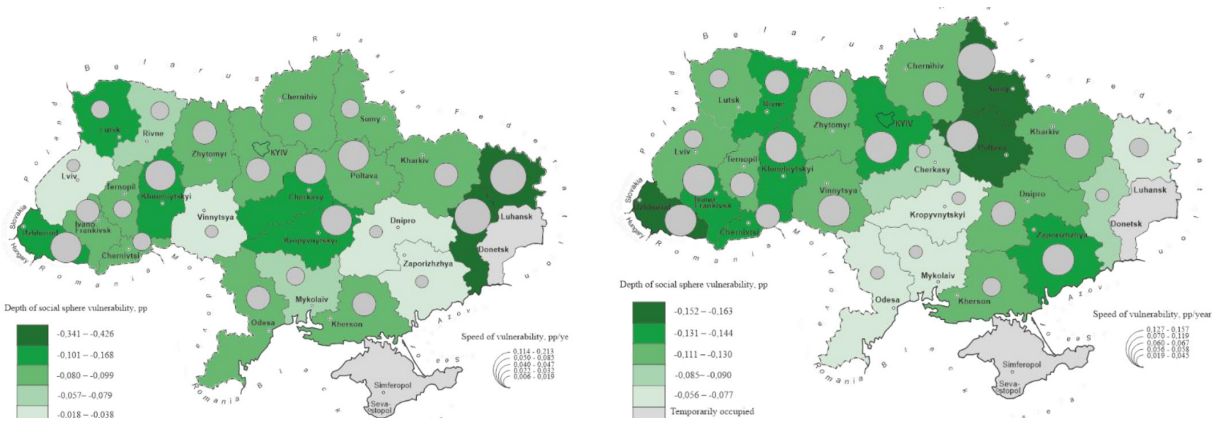
The full-scale war of 2022 significantly increased the vulnerability of the labor markets, especially in Central and Eastern Ukraine, drastically reducing the pace of recovery. The large-scale forced migration, the infrastructure destruction, and the loss of the labor potential critically weakened the adaptive capacity. Thus, the speed and duration of the recovery of the regional labor markets are determined by the combination of the depth and nature of the shock, the sectoral structure of the regional economy, and the institutional capacity, which leads to the uneven formation of resilience in the spatial dimension.

The social sphere is among the most vulnerable to systemic crises, as confirmed by the empirical evidence. The 2014 macroeconomic shock caused significantly higher losses in the social sphere than in the other components of socio-economic vulnerability, despite the social development indicators being relatively higher than those of the labor market, the demographic sphere, and the economic system. For instance, the average annual social development index in the period from 2010-2013 ranged from 0.895 to 0.912, compared to 0.654-0.689 for the labor market. In 2014, the national average loss in social development reached 0.3 pp, with the highest losses seen in Donetska (0.3 pp) and Luhanska (0.4 pp) oblasts, and the lowest in Dnipropetrovska (0.06 pp), Zaporizka (0.018 pp), and Lvivska (0.038 pp). In the period from 2020 to 2021, social sphere losses averaged 0.05 pp, which is 0.25 pp lower than in 2014. However, the losses across all the regions in 2021 were 0.05-0.07 pp higher than in the period from 2014 to 2015, indicating declining regional adaptability and elasticity to repeated shocks.

The period of vulnerability of the social system reflects the limited capacity of the regions to sustain development while minimizing losses. The empirical evidence reveals strong territorial differentiation: the longest vulnerability periods were observed in Lvivska Oblast (5 years) and Vinnytska and Volynska oblasts (4 years), indicating prolonged exposure to shocks and slower institutional adaptation. In contrast, Poltavska Oblast showed the shortest vulnerability period (1 year), thus suggesting a higher capacity of the social infrastructure to absorb shocks. However, shorter vulnerability periods did not necessarily correspond to the lower losses. For example, the vulnerability rate of the social sector in Poltavska Oblast was four times higher than in Zaporizka Oblast despite the latter having a longer three-year vulnerability period, highlighting the nonlinearity between the duration and intensity of losses.

In 2021, Vinnytska, Zhytomyrska, and Sumska oblasts formally exhibited the shortest vulnerability periods (1 year); yet they recorded some of the highest vulnerability speeds (0.129, 0.130, and 0.160 pp/year), indicating rapid destabilization followed by a relatively fast recovery. Conversely, Lvivska, Mykolayivska, Zaporizka, Volynska, and Dnipropetrovska oblasts became leaders in the average vulnerability speed due to the combined effects of the 2014 and 2020 shocks, confirming the complex nature of social resilience. In the period from 2014 to 2015, Donetska and Luhanska oblasts experienced the highest vulnerability rates (0.511 and 0.426), driven by military actions, the forced migration, and the degradation of the social infrastructure, while Zaporizka (0.027) and Poltavska (0.042) showed the lowest vulnerability. In the period from 2020 to 2021, higher vulnerability shifted to Poltavska (0.163), Ternopilska (0.130), and Zakarpatska (0.152) oblasts, reflecting the differentiated impact of the COVID-19 pandemic. The average recovery period across the regions remained about four years, with the recovery speeds ranging from 0.020 to 0.088 pp/year. At the national level, the average recovery speed of 0.09 pp/year indicates the formation of a safety margin and the strengthening of overall social resilience.

Zhytomyrska and Lvivska oblasts were characterized by relatively high recovery speeds (above 0.04 pp/year), indicating more flexible and adaptive social structures. In contrast, Donetska, Luhanska, and



a) 2014 b) 2021

Figure 2 The vulnerability of the social sphere in the Ukrainian regions: The spatial and dynamic approach, 2014, 2021

Source: Authors

Odeska oblasts demonstrated the recovery speeds below 0.02 pp/year, reflecting prolonged social stress and systemic weaknesses. This asymmetry confirms the uneven nature of regional resilience: while some territories compensate for the losses rapidly, others remain trapped in extended recovery cycles, increasing long-term vulnerability.

Since the 2000s, Ukraine has experienced large-scale socio-economic transformations that have profoundly reshaped its demographic structures. Demographic processes act both as a consequence of economic change and as an active factor influencing development trajectories and resilience. The current trends (the natural population decline and the intensive migration) have weakened demographic resilience across the regions. As a key institutional condition for economic growth, demographic resilience implies stable age, gender, and occupational structures capable of sustaining socio-economic systems under shocks. Therefore, analyzing its link with economic growth is of both theoretical and practical importance, particularly for postwar recovery.

Even before the shocks, several oblasts (Chernihivska, Harkivska, Luhanska, and Donetska) had had low demographic security due to depopulation and population aging (Figure 3). The 2014-2015 crisis accelerated these trends, with Donetska and Luhanska losing 0.3 pp each, while Ternopilska lost 0.2 pp and several other regions lost 0.1 pp, indicating the nationwide spread of demographic risks. The COVID-19 pandemic further destabilized demographic resilience, with the largest losses in Zaporizka (0.13 pp), Lvivska (0.11 pp), and Kirovohradska (0.1 pp). Overall, demographic resilience in Ukraine remains fragile, shaped by the long-term structural decline and repeated shocks, and its weakening directly undermines the labor market stability, the social protection systems, and the regional economic recovery capacity.

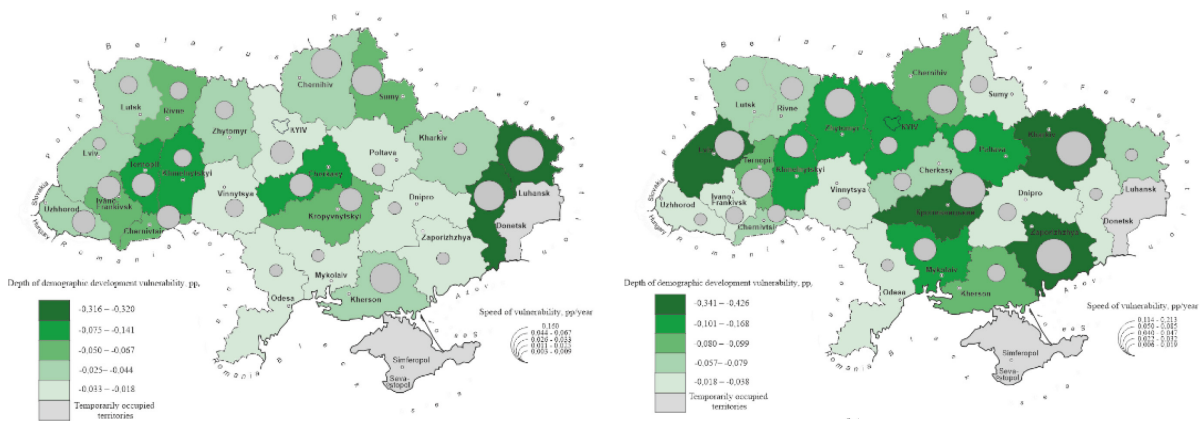
In the period from 2020 to 2021, several regions demonstrated positive or stable dynamics in the demographic security indicator, including Vinnytska (0.01 pp), Ivano-Frankivska (+0.02 pp), and Dnipropetrovska (0.01 pp) oblasts. The smallest average demographic losses in the period from 2010 to 2021 were observed in Zakarpatska (0.02 pp) and Odeska (-0.01 pp) oblasts, indicating relatively stable demographic development. Demographic vulnerability is a dynamic indicator shaped by long-term trends and shocks. Since 2014, the rate of vulnerability change has gradually declined,

reflecting the increased adaptive capacity of the regional demographic systems. The vulnerability values ranged from 0.009 to 0.799, with the maximum recorded at the five-year lag after 2014, indicating the concentration of demographic risks in certain regions (Annex C). The lowest vulnerability levels (around 0.01) were typical for short-term periods of 1-2 years.

The analysis for the period between 2010 and 2021 reveals pronounced spatial and temporal asymmetries. The average vulnerability rates varied from 0.002 to 0.160 pp/year, with the highest values observed at the 2.5-year lag after the 2014 shock, highlighting delayed but severe effects of the military conflict and mass displacement. The short-term lags showed lower vulnerability, whereas the medium-term effects accumulated more sharply. During the COVID-19 period, demographic vulnerability fluctuated less, possibly due to the short-term nature of the shock and the temporary restrictions on external migration.

The longer vulnerability periods were associated with the higher cumulative losses: the five-year lag generated the total vulnerability of 0.799 pp, whereas the one-year lags produced much lower values. However, the vulnerability speed did not increase linearly with the duration: the highest rate (0.160 pp/year) occurred at a 2.5-year lag, while the longer periods showed slower growth, indicating a shift from acute shocks to a gradual structural decline. Donetska, Lvivska, and Ternopilska oblasts had the longest vulnerability periods in 2014, while in the period from 2020 to 2021, the prolonged exposure shifted to Kyivska and Hersonska oblasts. The fastest vulnerability growth in the period from 2014 to 2015 occurred in Luhanska and Donetska oblasts, whereas during the pandemic period, the most affected regions were Zaporizka, Kirovohradska, Harkivska, and Ternopilska. This shift confirms that demographic instability has expanded beyond the conflict zones and increasingly reflects nationwide economic and pandemic-related pressures.

Ukraine's economic development depends on effective economic processes, competitive industrial structures, and balanced regional restructuring, supported by a strong social foundation that enhances the quality of life and reduces regional vulnerability to shocks. The period of the economic vulnerability of the Ukrainian regions ranged from one to six years. The maximum vulnerability period was observed in those regions that experienced prolonged shocks, such as military operations (Donetska and Luhanska



a) 2014 b) 2021

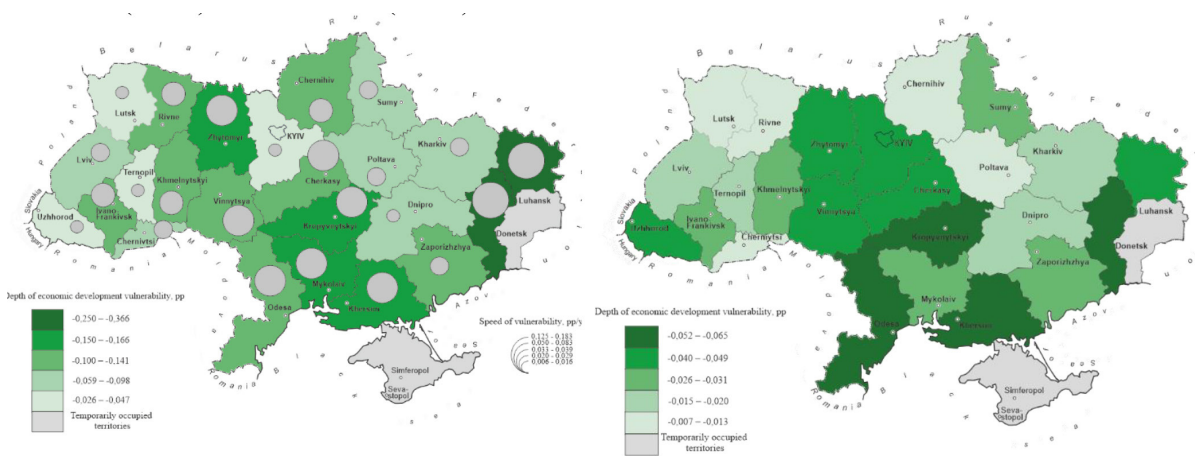
Figure 3 The vulnerability of the demographic development of the Ukrainian regions: The spatial and dynamic approach, 2014, 2021

Source: Authors

oblasts, the vulnerability period was six years). On the other hand, the regions with a short (one to two years) vulnerability period (Volynska and Zakarpatska oblasts) demonstrated high resilience to macroeconomic shocks. As an indicator that reflects the pace of regional adaptation to shocks, the speed of vulnerability shows a significant differentiation between the regions in terms of economic resilience in the period from 2014 to 2015 and from 2020 to 2021 (Annex D). The highest speed of vulnerability was observed in Luhanska Oblast (0.160 pp/year), which is related to the critical impact of military operations, and the lowest values of the vulnerability speed were typical for the regions with a low level of risk, for example, Volynska Oblast (0.004 pp/year). For most regions, the speed of vulnerability ranged between 0.01 and 0.05 pp/year.

The level of the economic vulnerability of the regions was the highest during the crisis periods (2014-2015) due to the security factors and the significant weakening of the economic and resource potential of the territories. In the period from 2020 to 2021, the impact of COVID-19 on the economic development was less evident compared to the previous crises, with the exception of a few oblasts (Figure 4). In particular, the lowest level of average vulnerability was recorded in Volynska (0.009) and Zakarpatska (0.014) oblasts, which indicates a high rate of the socio-economic resilience of the regions. The highest level of average vulnerability was observed in Donetska (0.175) and Luhanska (0.349) oblasts.

For most regions, the recovery period after the 2014 shock averaged four to five years, but by 2021, it had shortened to one to two years. This compression reflects both growing adaptation to the recurrent crises and the declining capacity for a full recovery under prolonged shocks. Volynska Oblast was an exception with the longest recovery period (3.5 years), indicating structural rigidity. Despite the impacts of severe conflicts, Donetska Oblast showed the highest post-2014 recovery speed (0.050 pp/year), reaching the recovery indicator of 0.624, while most other regions lagged. In 2021, the recovery indicators fell to the minimum levels (0.005-0.02) nationwide, simultaneously signaling deepening systemic vulnerability. Zakarpatska Oblast consistently demonstrated a low recovery speed and only a moderate recovery, reflecting a limited adaptive potential.



a) 2014 b) 2021

Figure 4 The vulnerability of the economic development of Ukraine's regions: The spatial and dynamic approach, 2014, 2021

Source: Authors

The resilience structure in 2014 reveals further contrasts. Despite direct exposure to military shocks, Luhanska and Donetska oblasts showed relatively high resilience, with the safety margin of 0.549 in Luhanska and the resistance level of 32.97% in Donetska, reflecting the buffering role of the pre-shock economic potential. In contrast, Vinnytska, Rivnenska, Ivano-Frankivska, and Cherkaska oblasts exhibited moderate resistance (10-20%) but a high recovery capacity (close to 1.0), indicating greater flexibility. Regional trajectories in the period from 2014 to 2021 diverged further. Kyivska, Kirovohradska, and Harkivska oblasts experienced a gradual decline in the safety margins and the recovery coefficients, pointing to the erosion of long-term resilience. Conversely, despite its low resistance in 2014 (5.16%), Zakarpatska Oblast maintained high recovery rates in both 2014 (1.02) and 2021 (0.99), demonstrating adaptive recovery despite weak structural resistance.

Overall, the regions with high initial safety margins tended to show stronger resistance, whereas those with the highest recovery rates displayed only moderate resilience. This duality confirms the multidimensional nature of resilience in Ukraine and highlights the need to assess it through a system of the interrelated indicators capturing resistance, recovery, and adaptability rather than a single composite measure.

CONCLUSION

The findings confirm that socio-economic resilience is a systemic characteristic defining the ability of Ukraine's regions to withstand shocks, reduce vulnerability, and recover in the post-shock period. The use of the composite spatiotemporal indicators, rather than a single integrated index, enabled a more nuanced assessment of the multidimensional nature of resilience and the identification of territorial asymmetries and structural bottlenecks. This approach captured the key consequences of the 2014-2015 shocks and the COVID-19 pandemic of 2020-2021, which led to declining labor market performance, increased demographic vulnerability, and deepening economic instability.

Testing the proposed methodology for the period from 2010 to 2021 revealed two major shocks that significantly weakened regional resilience. The labor market indicators declined by 6.4 percentage points in the period from 2010 to 2014, with regression observed in most regions, except Vinnytska, Volynska, Zhytomyrska, and Chernihivska oblasts. On average, Ukraine's labor market resilience indicator fell from 0.526 in 2014 to 0.025 in 2021. Demographic vulnerability proved highly dynamic, varying between 0.009 and 0.799, while economic vulnerability peaked in 2014-2015 due to the security factors and resource exhaustion; the pandemic-related effects in the period from 2020 to 2021 were comparatively less severe, except in several oblasts.

The results confirm the research hypotheses: resilience depends not only on the scale of losses but also on regional adaptive and recovery capacities, shaped by both internal structures and external shocks. The analysis is limited to the pre-war period (2010-2021) and thus reflects the baseline level of resilience that can serve as a benchmark for assessing the post-2022 challenges. The research is subject to certain methodological limitations. Since the analysis covers only the period from 2010 to 2021, it does not account for the unprecedented impact of the full-scale war, which has critically minimized the recovery capacity of the regional systems since 2022. Therefore, the findings should be regarded as reflecting the baseline (pre-war) level of resilience that can serve as a benchmark for subsequent comparisons and for assessing the scale of new challenges.

Further studies should focus on integrating the consequences of the full-scale war into resilience assessment models, as well as on adapting and testing the best international practices for building regional resilience in post-war conditions. Equally important is the need to combine short-term vulnerability management with the development of long-term adaptability and design a system of threshold values of resilience at the national and regional levels within the framework of Ukraine's European integration processes.

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ANNEXES

ANNEX A

The indicators of the resilience of the regional labor market: **Vulnerability** to macroeconomic shocks, 2010-2021

Regions	Vulnerability indicators								
	Losses (pp)			Period (years)			Speed (pp/year)		
	2014-2015	2020-2021	average	2014	2020-2021	average	2014	2021	average
Ukraine	-0.064	-0.100	-0.082	3	1	2	0.021	0.100	0.061
Vinnytska	-0.005	-0.017	-0.011	1	1	1	0.005	0.017	0.011
Volynska	-0.008	-0.063	-0.036	2	1	1.50	0.004	0.063	0.034
Dnipropetrovska	-0.004	-0.012	-0.008	1	1	1	0.004	0.012	0.008
Donetska	-0.216	-0.065	-0.141	3	1	2	0.072	0.065	0.069
Zhytomyrska	-0.013	-0.038	-0.026	1	1	1	0.013	0.038	0.026
Zakarpatska	-0.014	-0.090	-0.052	3	1	2	0.005	0.090	0.047
Zaporizka	-0.058	-0.069	-0.064	2	1	1.5	0.029	0.069	0.049
Ivano-Frankivska	-0.004	-0.095	-0.050	3	1	2	0.001	0.095	0.048
Kyivska	-0.007	-0.025	-0.016	5	1	3	0.001	0.025	0.013
Kirovohradska	-0.024	-0.072	-0.048	2	1	1.5	0.012	0.072	0.042
Luhanska	-0.247	-0.068	-0.158	4	2	3	0.062	0.034	0.048
Lvivska	-0.030	-0.053	-0.042	2	1	1.50	0.015	0.053	0.034
Mykolayivska	-0.015	-0.080	-0.048	3	1	2	0.005	0.080	0.043
Odeska	-0.015	-0.034	-0.025	2	1	1.5	0.008	0.034	0.021
Poltavska	-0.079	-0.083	-0.081	2	1	1.5	0.040	0.083	0.061
Rivnenska	-0.054	-0.067	-0.060	3	1	2	0.018	0.067	0.043
Sumska	-0.008	-0.026	-0.017	3	1	2	0.003	0.026	0.014
Ternopilska	0.004	-0.086	-0.041	1	1	1	0.004	0.086	0.045
Harkivska	-0.017	-0.042	-0.030	2	1	1.5	0.009	0.042	0.025
Hersonska	-0.043	-0.037	-0.040	5	1	3	0.009	0.037	0.023
Hmelnytska	0.006	-0.084	-0.039	2	1	1.5	0.003	0.084	0.044
Cherkaska	-0.004	-0.033	-0.019	2	1	1.5	0.002	0.033	0.018
Chernivetska	-0.012	-0.068	-0.040	3	2	2.5	0.004	0.034	0.019
Chernihivska	-0.033	-0.074	-0.054	2	1	1.5	0.017	0.074	0.045

Source: Authors

ANNEX B

The indicators of the resilience of the regional social system: **Vulnerability** to macroeconomic shocks, 2010-2021

Regions	Vulnerability indicators									
	Period (years)			Speed (pp/year)			Vulnerability			
	2014	2020-2021	average	after 2014	2021	average	2014-2015	2020-2021	average	Total
Ukraine	1	1	1	0.263	0.050	0.156	0.132	0.025	0.078	0.156
Vinnytska	4	1	2.5	0.017	0.119	0.068	0.138	0.060	0.099	0.198
Volynska	4	2	3	0.026	0.058	0.042	0.209	0.116	0.162	0.325
Dnipropetrovska	3	2	2.5	0.019	0.065	0.042	0.085	0.129	0.107	0.214
Donetska	3	2	2.5	0.114	0.045	0.079	0.511	0.090	0.300	0.601
Zhytomyrska	2	1	1.5	0.050	0.127	0.088	0.099	0.063	0.081	0.163
Zakarpatska	2	2	2	0.084	0.076	0.080	0.168	0.152	0.160	0.319
Zaporizka	3	2	2.5	0.006	0.070	0.038	0.027	0.141	0.084	0.168
Ivano-Frankivska	2	2	2	0.040	0.070	0.055	0.081	0.140	0.110	0.221
Kyivska	2	2	2	0.044	0.072	0.058	0.088	0.144	0.116	0.232
Kirovohradska	2	2	2	0.060	0.038	0.049	0.119	0.077	0.098	0.196
Luhanska	2	1	1.5	0.213	0.057	0.135	0.426	0.028	0.227	0.455
Lvivska	5	2	3.5	0.008	0.056	0.032	0.096	0.111	0.104	0.208
Mykolayivska	3	3	3	0.026	0.019	0.022	0.118	0.085	0.101	0.202
Odeska	2	2	2	0.047	0.033	0.040	0.093	0.066	0.080	0.160
Poltavska	1	2	1.5	0.085	0.082	0.083	0.042	0.163	0.103	0.206
Rivnenska	3	2	2.5	0.022	0.065	0.044	0.099	0.131	0.115	0.230
Sumska	3	1	2	0.027	0.157	0.092	0.120	0.078	0.099	0.198
Ternopilska	3	2	2.5	0.031	0.065	0.048	0.141	0.130	0.136	0.271
Harkivska	2	2	2	0.046	0.060	0.053	0.093	0.120	0.107	0.213
Hersonska	2	2	2	0.041	0.057	0.049	0.082	0.115	0.098	0.197
Hmelnytska	2	2	2	0.050	0.071	0.061	0.101	0.142	0.121	0.242
Cherkaska	2	2	2	0.062	0.042	0.052	0.123	0.085	0.104	0.208
Chernivetska	3	2	2.5	0.031	0.067	0.049	0.140	0.134	0.137	0.274
Chernihivska	3	2	2.5	0.032	0.063	0.048	0.143	0.127	0.135	0.270

Source: Authors

ANNEX C

The indicators of the resilience of the regional demographic system: **Vulnerability** to macroeconomic shocks, 2010-2021

Regions	Vulnerability indicators									
	Period (years)			Speed (pp/year)			Vulnerability			
	2014	2020-2021	average	after 2014	2021	average	2014-2015	2020-2021	average	total
Ukraine	2	3	2.5	0.006	0.019	0.012	0.013	0.084	0.048	0.097
Vinnytska	1	2	1.5	0.011	0.005	0.008	0.005	0.010	0.008	0.015
Volynska	2	3	2.5	0.012	0.008	0.010	0.025	0.034	0.030	0.059
Dnipropetrovska	1	1	1.0	0.004	0.014	0.009	0.002	0.007	0.005	0.009
Donetska	5	3	4.0	0.063	0.002	0.033	0.790	0.009	0.400	0.799
Zhytomyrska	2	1	1.5	0.016	0.096	0.056	0.031	0.048	0.040	0.080
Zakarpatska	1	2	1.5	0.031	0.004	0.017	0.015	0.008	0.011	0.023
Zaporizka	2	1	1.5	0.009	0.125	0.067	0.018	0.062	0.040	0.081
Ivano-Frankivska	2	1	1.5	0.027	0.019	0.023	0.054	0.010	0.032	0.064
Kyivska	1	6	3.5	0.033	0.013	0.023	0.017	0.243	0.130	0.259
Kirovohradska	2	1	1.5	0.032	0.100	0.066	0.063	0.050	0.057	0.113
Luhanska	2	3	2.5	0.160	0.007	0.083	0.320	0.029	0.175	0.349
Lvivska	5	2	3.5	0.008	0.056	0.032	0.096	0.111	0.104	0.208
Mykolayivska	2	2	2.0	0.003	0.038	0.020	0.005	0.076	0.041	0.081
Odeska	1	2	1.5	0.005	0.009	0.007	0.002	0.018	0.010	0.020
Poltavska	2	2	2.0	0.003	0.038	0.020	0.005	0.076	0.041	0.081
Rivnenska	2	1	1.5	0.025	0.033	0.029	0.050	0.016	0.033	0.067
Sumska	1	1	1.0	0.067	0.015	0.041	0.034	0.007	0.021	0.041
Ternopilska	5	1	3.0	0.028	0.060	0.044	0.352	0.030	0.191	0.382
Harkivska	3	1	2.0	0.008	0.103	0.056	0.038	0.051	0.045	0.089
Hersonska	1	4	2.5	0.044	0.014	0.029	0.022	0.116	0.069	0.137
Hmelnytska	3	3	3.0	0.025	0.031	0.028	0.112	0.140	0.126	0.252
Cherkaska	3	2	2.5	0.026	0.013	0.019	0.117	0.025	0.071	0.142
Chernivetska	2	2	2.0	0.033	0.017	0.025	0.066	0.034	0.050	0.100
Chernihivska	1	1	1.0	0.044	0.071	0.058	0.022	0.036	0.029	0.058

Source: Authors

ANNEX D

The indicators of the resilience of the regional economic system: **Vulnerability** to macroeconomic shocks, 2010-2021

Regions	Vulnerability indicators									
	Period (years)			Speed (pp/year)			Vulnerability			
	2014	2020-2021	average	after 2014	2021	average	2014-2015	2020-2021	average	total
Ukraine	3	1	2.0	0.057	0.011	0.034	0.259	0.005	0.132	0.264
Vinnytska	2	1	1.5	0.058	0.049	0.054	0.117	0.025	0.071	0.141
Volynska	3	1	2.0	0.011	0.010	0.010	0.048	0.005	0.027	0.053
Dnipropetrovska	5	2	3.5	0.016	0.008	0.012	0.202	0.015	0.109	0.217
Donetska	2	2	2.0	0.125	0.026	0.075	0.250	0.052	0.151	0.301
Zhytomyrska	2	1	1.5	0.083	0.043	0.063	0.166	0.022	0.094	0.188
Zakarpatska	4	2	3.0	0.006	0.022	0.014	0.052	0.045	0.048	0.096
Zaporizka	5	1	3.0	0.022	0.027	0.025	0.273	0.014	0.144	0.287
Ivano-Frankivska	3	1	2.0	0.033	0.026	0.030	0.150	0.013	0.082	0.163
Kyivska	4	3	3.5	0.012	0.016	0.014	0.095	0.070	0.083	0.165
Kirovohradska	2	1	1.5	0.075	0.057	0.066	0.151	0.028	0.089	0.179
Luhanska	2	3	2.5	0.183	0.014	0.098	0.366	0.061	0.214	0.428
Lvivska	2	1	1.5	0.029	0.020	0.025	0.059	0.010	0.034	0.069
Mykolayivska	2	1	1.5	0.075	0.031	0.053	0.150	0.015	0.083	0.166
Odeska	2	1	1.5	0.050	0.053	0.052	0.100	0.027	0.063	0.127
Poltavska	4		4.0	0.023		0.023	0.182	0.000	0.091	0.182
Rivnenska	3	1	2.0	0.039	0.012	0.026	0.176	0.006	0.091	0.183
Sumska	3	1	2.0	0.028	0.029	0.028	0.125	0.014	0.070	0.140
Ternopilska	4	2	3.0	0.010	0.009	0.010	0.081	0.018	0.050	0.099
Harkivska	4	1	2.5	0.024	0.017	0.021	0.194	0.008	0.101	0.202
Hersonska	2	1	1.5	0.077	0.065	0.071	0.154	0.033	0.094	0.187
Hmelnytska	3	2	2.5	0.036	0.015	0.025	0.160	0.030	0.095	0.190
Cherkaska	2	1	1.5	0.071	0.040	0.055	0.141	0.020	0.081	0.161
Chernivetska	5	1	3.0	0.020	0.013	0.016	0.245	0.006	0.126	0.252
Chernihivska	3	1	2.0	0.039	0.007	0.023	0.176	0.003	0.090	0.179

Source: Authors