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Economic resiliency and recovery, lessons from the financial crisis for the COVID-19 pandemic: A regional perspective from Central and Eastern Europe

Josef C. Brada [a,b], Paweł Gajewski [c], Ali M. Kutan [d,e,*]

[a] Arizona State University, United States
[b] CERGE- Economic Institute of the Czech Academy of Sciences and Charles University, Czechia
[c] Faculty of Economics and Sociology, University of Łódź, Poland
[d] Southern Illinois University, Edwardsville, United States
[e] The Society for the Study of Emerging Markets, United States

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ABSTRACT

In this paper we examine resiliency, the ability to absorb and recover from economic shocks, in 199 Nuts-3 regions in Central and Eastern Europe (CEE) following the 2008 global financial crisis. We find evidence of strong positive regional spillovers, meaning that regions tend to form clusters of high-performing and low-performing areas, a process that exacerbates regional income disparities. Using the experience of the recovery from the 2008 financial crisis, we simulate the effects of the COVID-19 pandemic on the ability of these, and, by extension, other upper-middle-income countries to recover from a shock to employment caused by the incidence of COVID-19. Using our recoverability equation estimates, we find that employment in no more than 31 of the 199 regions will have fully recovered in 2 years after the onset of the recovery from the crisis. Policy implications of the findings are discussed.

1. Introduction

In the span of less than two decades the global economy has faced two major shocks, the global financial crisis that began in 2008 and the COVID-19 pandemic that began in 2020.

In this paper we use Central and East European (CEE) countries' response to, and recovery from, the employment shock caused by the financial crisis to estimate the regional patterns of recovery from the crisis at the NUTS-3 level. Using spatially correlated models of regional response and recovery we show that the crisis had important regional effects through spillovers among neighboring regions, leading to growing regional income differences. We then use the pattern of recovery from the financial crisis to simulate recovery from the shock to employment caused by the COVID-19 pandemic. We simulate the recovery using a range of assumptions about the length of the pandemic and the depth of unemployment experienced. We find that recovery will be slow so that, under conservative assumptions about the course of the pandemic, very few regions of CEE will have recovered pre-pandemic levels of employment even two years after the start of economic recovery.

The slow recovery from the global financial crisis of 2008 sparked a renewed interest in the concepts of economic resiliency, the ability of economies to absorb economic shocks and to recover from them. Traditional thinking in macroeconomics had been that downturns were temporary, and that the economy would return to the long-run growth path of GDP as idle workers and capital were put back to work. The aftermath of the 2008 crisis called this view into question. The data on output and employment from many countries showed that few economies were able to recover to the pre-crisis trend of real GDP growth. Ball (2014), Haltmaier (2012), Martin, Munyan, and Wilson (2014) and Reinhart and Rogoff (2014), using different methodologies and data sets, all demonstrated intercountry differences in resistance to the shock of the global financial crisis and in the recovery from it. The economies of Central and Eastern Europe (CEE) also showed diverse responses to

* Corresponding author.
E-mail address: akutan@siue.edu (A.M. Kutan).

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the crisis. Some, such as the Baltic states, suffered large and swift declines in economic activity while others, most notably Poland, managed to avoid a recessionary contraction in output. Similarly, the speed of recovery from the crisis differed among the CEE countries.

At the national and the regional levels, a return to the economic *status quo ex ante* is difficult because shocks create shortfalls in labor, capital and technology related to the decline in output. Reduced investment during the downturn lowers the capital to labor ratio, workers leave the labor force, sometimes permanently, thus reducing the labor force participation rate and, while they are unemployed, they cease to acquire additional human capital from learning by doing on the job, and their existing skills atrophy (Orlowski, 2020). Research and development also decline, and, together with lower levels of investment in capital that embodies new technology, reduce the level and growth of total factor productivity. National-level recovery from the effects of the crisis also depends on economic characteristics such as the structure of the economy, the openness to trade, the exchange rate regime, etc., on the counter-cyclical policies and measures reversing the decline in productivity and the supply of factors of production that are adopted, as well as on social characteristics such as solidarity, low levels of corruption, etc. (see, for example, Evrensel, 2010; Iyer, Kitson, & Toth, 2005). To the extent that the shock changes relative prices and wages, structural changes are also an important component of resistance and recovery.

In this paper, we examine resistance, to and the recovery from, the global financial crisis in CEE countries at the regional level, using NUTS-3 statistical regions of nine countries, Bulgaria, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia. We examine CEE resistance and recovery at the regional level for three reasons. The first is that, by focusing on regions of a single country rather than on cross-country comparisons, we can hold constant a number of variables that influence resistance and recovery. These include national counter-cyclical policies, the exchange rate regime, openness to international trade, and social policies, and national culture, all important country-level determinants of resiliency but ones that apply more equally to all regions within one country. A regional approach makes it easier to identify the effects of sub-national economic factors that play an important role in resistance and recovery. The second reason is that, in the regional economics literature, there is a lack of empirical research on regional economic resiliency as well as on the nature of regional spatial effects or spillovers from economic shocks in CEE economies. The final reason is that regional developments in the transition economies of Central and Eastern Europe are very similar to those in many upper- and middle-income countries (Dijkstra, Garcilazo, & McCann, 2015; Storper, 2018), and thus the transition economy experience has lessons for a much broader range of countries.

We find significant clustering of similar economic regions both within CEE countries and even across the borders of the sample countries. Moreover, there are important spillover effects between regions both from the economic outcomes they generate and from their economic characteristics. Our results further indicate that the length of the downturn caused by the 2008 financial crisis and the ability of regions to adjust their economic structure during the downturn and afterward are important components to recoverability. Our simulation results show that recovery from the effects of COVID-19 on employment will be slow and, after a two-year recovery period, most regions will not have fully recovered the pre-pandemic level of industrial employment.

The remainder of the paper is organized as follows: Section 2 reviews the literature on regional resiliency in CEE, the literature on financial market reactions to the pandemic, studies of possible policy measures to reduce the spread and intensity of the pandemic, and it closes by relating our research strategy to the lacunae identified in the studies we review. Section 3 discusses the CEE experience during the financial crisis. Section 4 sets out the models of spatial resistance and recoverability and of regional spillovers used in this paper, and Section 5 explains the data sources and main variables of interest. Section 6 presents the estimates of the direct and indirect effects of CEE regional characteristics as displayed during the financial crisis. These then serve as the basis of our simulations of the likely pattern of recovery following the COVID-19 shock to industrial employment, which are presented in Section 7.[1] Section 8 concludes.

2. Literature survey

2.1. Regional spillovers in CEE countries

There is limited research on the regional economic resiliency of CEE economies, but studies of the economic characteristics of CEE regions point to the existence of regional spillovers and to systematic economic differences between regions. Elhorst, Blien, and Wolf (2007) estimate a spatial wage curve for Eastern German districts during 1993–1999 and report that estimates of unemployment elasticities are sensitive to the inclusion of spatially correlated error terms in their specifications. Baltagi and Rokicki (2014) estimate the spatial wage curve for Poland using individual data from the Polish Labor Force Survey at the NUTS-2 level, and they report significant spatial unemployment spillovers across regions. Kholodilin, Oshchepkov, and Siliverstovs (2012) find significant convergence of income levels among high-income regions in Russia that are located near each other, also suggesting the existence of, in this case, positive spatial spillovers between regions.

Because of these spatial spillovers, in CEE countries there has been a divergence in regional economic performance that was evident both before and after the financial crisis, suggesting important regional differences in the response to shocks. Shortly after the start of the transition, regional disparities in income and employment had already became increasingly evident (Petrakos, 1996, 2001) due to the inability of some regions to adapt to the shock of transition to a market economy (Fazekas, 1996) in large part because of their structural characteristics (Ezcurra & Pascual, 2007; Monastiriotis, Kallioras, & Petrakos, 2017). Moreover, throughout the past twenty years, higher productivity, per capita GDP and population growth have characterized CEE's capital cities and the regions surrounding them (Babecký & Komárek, 2020; Neumann, Budde, & Ehlert, 2014). Thus, even as the CEE countries have been catching up with the old EU members in terms of per capita GDP, within the CEE countries, incomes and productivity have been diverging between the rich and poor regions. Understanding the regional patterns of resistance and recovery is critical for understanding the likely response of the CEE countries, and by extension, of other similar countries, to the COVID-19 pandemic because the effects of the pandemic can have strong regional spillovers. The experience of countries such as Italy and the United States and others shows that eventually most regions are affected by the pandemic to a similar extent. Nevertheless, regional spillovers mean that a similar initial shock to all regions will result in very different outcomes as regional spillovers make themselves felt and this is the process that we address.

2.2. Financial market reactions to COVID-19

Because our paper deals with recovery from the COVID19 pandemic,

[1] At first glance, it might seem more appropriate to use information about the effects of past mass infection episodes in CEE to model the response to the COVID-19 pandemic rather than basing our simulations on the experience of the financial crisis. However, there are no previous pandemic episodes in CEE that had very large economic effects. For example, according to official statistics, there were no cases of Ebola or SARS in Poland whatsoever and only one case of SARS in the entire CEE. As for the H1N1 virus, its cumulative number of cases in CEE was lower than the number of new COVID-19 cases recorded in Poland on any day in the last months of 2020. The magnitude of the economic shock associated with COVID-19 can only be compared to the 2008 crisis, although the 2008 crisis nevertheless looks rather mild in comparison.

we selectively review recent studies to provide context for our contribution to this literature. The review highlights the major areas of research undertaken since the beginning of the pandemic. These studies show that, when studied from different angles, the contemporaneous effects of the pandemic have been significant and multidimensional.[2]

Numerous studies have examined the association between the pandemic and financial markets on the assumption that financial markets react rapidly to news of pandemic developments, thus providing a sort of early warning system regarding the economic effects of COVID-19 spread. For example, Corbet, Larkin, and Lucey (2020) find significant volatility correlation between Chinese stock market indices and the bitcoin during the peak of the pandemic. Akhtaruzzaman, Boubaker, and Sensoy (2020) report a significant increase in correlations of stock market returns between China and G7 countries during the pandemic period, which is higher for financial firms than non-financial firms. Sharif, Aloui, and Yarovaya (2020) find significant connectedness between confirmed COVID-19 cases and measures of economic policy uncertainty, geopolitical risk and stock market returns in the US. They show that the outbreak had a more significant effect on both economic uncertainty and on geopolitical risk than on the stock market. In examining the association between the daily returns of the top cryptocurrencies and different intensity levels of the COVID-19 cases, Iqbal, Fareed, and Guangcai (2020) find that the association is asymmetric and changes in scale and direction at different quantiles. Mnif, Jarboui, and Mouakhar (2020) COVID-19 find that the cryptocurrency market became more efficient after the onset of the pandemic, likely due the increased volume of trading on these markets. Ji, Dayong, and Zhao (2020) examine several safe- haven assets during the pandemic and find that gold and soybean commodity futures retain their status as safe-haven assets while bitcoin, foreign currencies and the crude oil commodity futures become weaker safe-haven assets. Taken together, these studies reflect the connectedness of financial markets and of asset categories as well as the reallocation of investments as the pandemic accelerated, a result of the negative turn in investors' expectations.

Other studies have focused on the performance of equity markets during the pandemic. Generally, asset returns are sensitive to the rise of COVID-19 cases or deaths. Ali, Alam, and Rizvi (2020) report that the significantly negative performance of equities and of commodities as well as increases in the volatility of their returns are related to reported increases in COVID-19 deaths. Al-Awadhi, Al-Saifi, Al-Awadhi, and Alhamadi (2020) document a significant decline in the stock returns of Chinese firms related to the confirmed numbers of coronavirus cases and deaths. Corbet, Hou, Hu, Lucey, and Oxley (2020) take a reputational-based contagion view of COVID-19 and show the firms that that have corona-related corporate or brand names perform negatively during the pandemic.

In addition to reacting to news about COVID-19 infections or deaths, investors react to other COVID related news, such as news of policy measures and other announcements by the authorities. Rizwan, Ahmad, and Ashraf (2020) find that the systemic risk in the banking sectors of affected countries increased initially and then leveled off around April 2020. Several studies have examined the reaction of markets to pandemic related news, including policy interventions and stay-at-home policies. Using Chinese financial market data, Corbet, Larkin, and Lucey (2020) show that domestic stocks reacted to COVID-19 announcements earlier than did those of international companies, and they argue that this finding is evidence of informational asymmetry. In examining the reaction of US industry returns to COVID-19 related news and policy announcements, Goodell and Huynh (2020) report that some sectors such as restaurants and hotels saw negative abnormal returns while others, including medical and pharmaceutical products sectors, had abnormal positive returns. Bickley, Brumpton, Chan, Colthurst, and Torgler (2020) find significant correlations between the trading volumes of 26 stock markets and number of confirmed and death cases. They report significant structural breaks in traded values in 15 of the 28 indices due to stay-at-home policy measures and show that such policy interventions have been able to stabilize the financial markets about 61% of the time in the sample countries. Schell, Wang, and Huynh (2020) examine the stock market reactions to the World Health Organization announcements for 26 indices since 2009 and they find that only COVID-19 related announcements generate negative abnormal returns for these indices. Using Google Search data on consumer panic news for 40 countries during the pandemic, Keane and Neal (2021) build a consumer buying panic index and show that both domestic and international virus transmission news and government policy announcements explain the movements in the panic index. These findings suggest that information flows in terms of both reported COVID-19 cases and policy interventions have been important determinants of financial price movements.

Other papers have examined whether the prediction of asset returns and their volatility has changed during the COVID-19 pandemic period. For example, using data on reported cases and death tolls from 20 countries, Salisu and Vo (2020) show that health news during the pandemic predicts stock returns well and outperforms a benchmark model based on average historical returns. Employing indices for 19 equity markets, Wang, Lu, He, and Ma (2020) test the usefulness of VIX and the economic policy uncertainty (EPU) index in predicting future volatility of the equity indices and find that the VIX is a better predictor than the EPU index during the pandemic period. Li, Liang, Ma, and Wang (2020) find that the Infectious Disease EMV tracker (IDEMV) is able to predict stock market volatility well in Germany, France and the UK. However, they show that the VIX has done a better job than IDEMV in predicting stock market volatility during the pandemic. Comparing the volatility effects of the pandemic to those of the 2008 global financial crisis, Shehzad, Xiaoxinga, and Kazouz (2020) report that the pandemic increased the variance of the stock markets in the US, Germany, and Italy more than did the global financial crisis. In examining the effects of the pandemic at the sectoral level for the world and for the US, Haroon and Rizvi (2020) find that the COVID-19 related news raises the volatility of these indices.

The literature also suggests that the relationship between COVID-19 incidence and asset returns is country specific, depending in part on how freely news is disseminated and on investors' faith in a country's institutions. Employing the Freedom House index of economic freedom for 75 countries, Erdem (2020) shows that stock returns in freer countries decline less and have lower volatility than do those in less-free nations. Topcu and Gulal (2020) find that equity markets in Asian emerging markets suffered the largest losses because of the pandemic while those in European emerging markets experienced lower losses.

2.3. Policies for dealing with the pandemic

Social distancing has been an important policy tool for fighting against the pandemic, but it has also been a source of policy and social controversies over its effectiveness and ways of implementing it. Several studies have examined the drivers of social distancing and other behavioral changes that could limit the spread of the virus. Using the Google COVID-19 community mobility reports and Hofstede's cultural factors for 58 countries, Huynh (2020) finds a negative association between Hofstede's uncertainty avoidance index and the number of people gathering in public, suggesting that countries with lower uncertainty avoidance are more likely to have a higher ratio of people gathering in public and hence less social distancing. Using unique survey data for the US, Papageorge et al. (2020) show that individuals with higher income, having more flexible arrangements for work such as having an internet access at home and additional space at home for working out of a home office are more likely to behave in ways that limit the spread of the virus,

[2] Atkeson (2020), Goodell (2020) and Guerrieri, Lorenzoni, Straub, and Werning (2020). provide early assessments of the economic and social impacts of COVID-19.

including social distancing. Using an extension of the survey data used by Papageorge et al. (2020) for six countries (China, Italy, Japan, South Korea, the UK, and the US), Dang, Huynh, and Nguyen (2020) find that the poor are less likely to alter behavior when they face virus prevention measures, supporting the findings of Papageorge et al. (2020) for the US. In addition, Dang et al. (2020) find that the biggest impact of the pandemic is on savings, particularly among low-income people. Moreover, they show that the distributional impacts of the pandemic are not uniform. For example, the nation that is the least likely to change its behavior in the face of the pandemic is Japan, the country with lowest drop in savings is the UK, and the nation where people are least likely to wash their hands and wear a mask is America. These findings suggest that policymakers need to consider such different economic and social factors of human behavior changes in designing strategies such as social distancing and stay-at-home policies to successfully fight against the virus.

2.4. Implications of the literature review for our research findings and strategy

This non-exhaustive review of the literature shows that financial markets have reacted to the COVID-19 pandemic, but it also confirms that increases in infections, in deaths and in policy announcements and measures create greater uncertainty for investors because, while a worsening COVID-19 situation clearly suggests worsening economic prospects, investors do not have a good gauge of the economic consequences of an intensification or lessening of the spread and intensity of the pandemic. Because the COVID-19 studies summarized above show that the poor are less likely to alter their behavior, our evidence of strong positive regional spillovers exacerbating regional income disparities suggests that behavioral changes such as social distancing are likely to be different among the regions, causing further challenges for policymakers to limit the spread of the virus. The simulations reported in this paper, while they are not able to predict the course the pandemic will take, do offer investors some guidance on the time path of economic recovery once the pandemic has run its course, thus helping them to allocate their investments over time and among asset classes. In this paper, to the best of our knowledge, for the first time in the literature, we employ a simulation approach to study the impact of the COVID-19 outbreak on real economic activity at a regional level. Hence, our study is unique in terms of its methodological contribution and its focus on real economic activity using regional data and capturing spatial spillovers across regions.

3. The CEE experience during the financial crisis

Table 1 shows the response of output, non-agricultural, and industrial employment during the financial crisis. All countries experienced a decline in GDP (Panel a), although there was considerable variation among countries. The biggest declines were in the Baltic countries, largely due to their exchange rate policies and reliance on domestic deflation to deal with the crisis. The post-crisis recovery saw most of the countries return to or surpass pre-crisis levels of GDP. There is also evidence of structural change during the response and recovery periods. Except for Poland and Hungary, employment shifted out of the non-agricultural sector (Panel b) and particularly out of industrial employment (Panel c).

In the subsequent analysis, we focus on the performance of employment in the non-agricultural sector in part because GDP at the NUTS-3 level is not available for some countries and, if available, only in nominal terms. Moreover, non-agricultural employment is more sensitive to changes in economic conditions, especially those due to external shocks. Agricultural employment, much of it self-employment, as well as agricultural output, are less likely to respond to changes in economic conditions because of the time it takes to alter crop and animal production and because some part of agricultural activities represents

Table 1
Resistance and recoverability in CEE countries during the global financial crisis.

Country	Decline in GDP (%)	Recovery in GDP(%)
Bulgaria	−6.5%	12.1%
Czechia	−5.8%	11.7%
Estonia	−19.8%	22.8%
Hungary	−7.9%	11.7%
Latvia	−23.3%	20.2%
Lithuania	−16.6%	23.7%
Poland	−0.4%	23.8%
Romania	−11.1%	16.7%
Slovakia	−9.4%	23.1%

Country	Decline in non-agricultural employment (%)	Recovery in non-agricultural employment
Bulgaria	−14.6%	4.3%
Czechia	−4.2%	4.0%
Estonia	−17.0%	16.1%
Hungary	−5.6%	14.1%
Latvia	−21.1%	7.6%
Lithuania	−15.6%	8.2%
Poland	−4.9%	7.2%
Romania	−11.7%	6.6%
Slovakia	−7.1%	6.0%

Country	Decline in industrial employment (NACE sectors B-E, %)	Recovery in industrial employment (NACE sectors B-E, %)
Bulgaria	−25.8%	3.3%
Czechia	−13.0%	11.2%
Estonia	−32.5%	16.1%
Hungary	−9.6%	17.2%
Latvia	−30.4%	8.0%
Lithuania	−24.9%	6.4%
Poland	−12.4%	8.2%
Romania	−21.5%	2.6%
Slovakia	−18.8%	12.2%

subsistence farming (Davidova, Fredriksson, & Bailey, 2009). Thus, regions with large agrarian populations would give the appearance of greater resistance merely due to the mix of agricultural and industrial employment. Finally, government policies to deal with the employment effects of shocks are largely directed toward the non-agricultural sector.

To put the regional responses in perspective, we examine responses in all regions of the nine countries. Specifically, we compare the non-agricultural employment change in each NUTS-3 region to the employment change averaged over all nine of the CEE countries. By using the CEE average job loss or gain, the relative resiliency of countries vis a vis each other is reflected in their regional resistance and recovery variables, but we are also able to capture regional differences in resilience within each country. Consider the following variable which captures the non-agricultural employment change in region i between the pre-crisis peak and the subsequent trough:

$$x_i = \frac{min\{e_{i2008}, e_{i2009}, \dots e_{i2013}\} - max\{e_{i2006}, e_{i2007}, e_{i2008}\}}{max\{e_{i2006}, e_{i2007}, e_{i2008}\}} * 100\% \tag{1}$$

where e_{i20xx} is the non-agricultural employment in region i in year 20xx. In this way we can allow for differences in the years in which the crisis began to be felt in different regions and also for differences in the years in which the effects of the crisis on employment reached their maximum. An examination of the data on employment showed that the years of peak employment were sometime between 2006 and 2008, and the trough occurred sometime between 2008 and 2013. Since the entire CEE region is our counterfactual, the following index could be taken to represent regional resistance in region i:

$$rescee_i = \frac{(x_i - x_{cee})}{|x_{cee}|} \quad (2)$$

where x_{cee} is the decline in employment from peak to trough in all CEE countries.

Since $x_i \leq 0$:

$$rescee_i = \begin{cases} 1 & \text{when there was no decline in employment in region } i \text{ during the crisis} \\ \in (0,1) & \text{when the region is more resilient than the CEE aggregate} \\ 0 & \text{when the region is as resilient as the CEE aggregate} \\ < 0 & \text{when the region is less resilient than the CEE aggregate} \end{cases}$$

A similar procedure can be adopted to calculate a measure of regional recoverability, which would be defined as the relative extent to which regional economies recovered, in terms of non-agricultural employment, between the trough of the crisis (anytime between 2008 and 2013) and the end of our sample, i.e. 2015. First, for each region we calculate:

$$y_i = \frac{e^*_{i2015} - min\{e_{i2008}, e_{i2009}, \dots e_{i2013}\}}{min\{e_{i2008}, e_{i2009}, \dots e_{i2013}\}} * 100\% \quad (3)$$

We use y_i to calculate an index of regional recoverability:

$$reccee_i = \frac{(y_i - y_{cee})}{y_{cee}} \quad (4)$$

where y_{cee} is the increase in employment from the trough to 2015 in all CEE countries.

Note that the values of $reccee_i$, unlike $rescee_i$, are not bounded, i.e.,

$$reccee_i : = \begin{cases} > 0 \text{ if the region had better recoverability than the CEE aggregate} \\ < 0 \text{ if the region had worse recoverability than the CEE aggregate} \end{cases}$$

Figs. 1 and 2 illustrate the $rescee_i$ and $reccee_i$ indices, respectively. Darker shades on the maps indicate regions with better resistance or recoverability relative to the CEE average. From Fig. 1 it is evident that several regions in Poland, as well as the central and suburban regions of the capital city of Bucharest, Romania did not experience a decline in employment during the crisis. Regions whose non-agricultural employment proved resistant relative to the average CEE experience were clustered in Czechia, Poland, and Slovakia, which reflects the relatively good performance of these economies at the onset of the crisis compared to other CEEs, as shown in Table 1. Nevertheless, there are clear regional differences in resistance in each country, and regions show clustering in their resistance, suggesting that regional characteristics and spillovers between regions were an important factor in resistance.

Measures of regional recovery relative to the CEE average are shown in Fig. 2. The most vigorous recovery was observed in a belt of Polish regions running from the north-central to the eastern part of the country and anchored by large cities, in Estonia and Hungary, followed by Lithuania. In both maps, Poland stands out as the most heterogenous country, encompassing both well and poorly performing regions. In all countries, the recovery of industrial employment shows strong clustering, indicative of regional spillovers.

While the above indices illustrate the economic performance of regions during the crisis, they have limits as precise measures of economic resilience. First, $rescee_i$ and $reccee_i$ are not stripped of country-wide

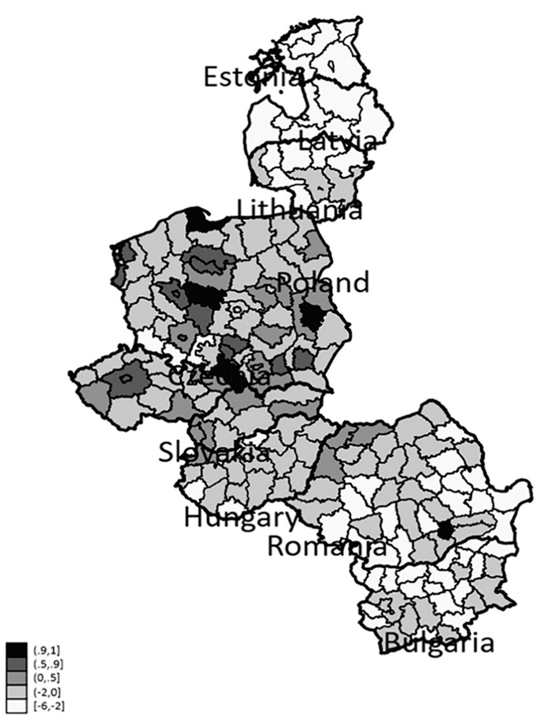

Fig. 1. Resistance of Regions Compared to the CEE Average (rescee).

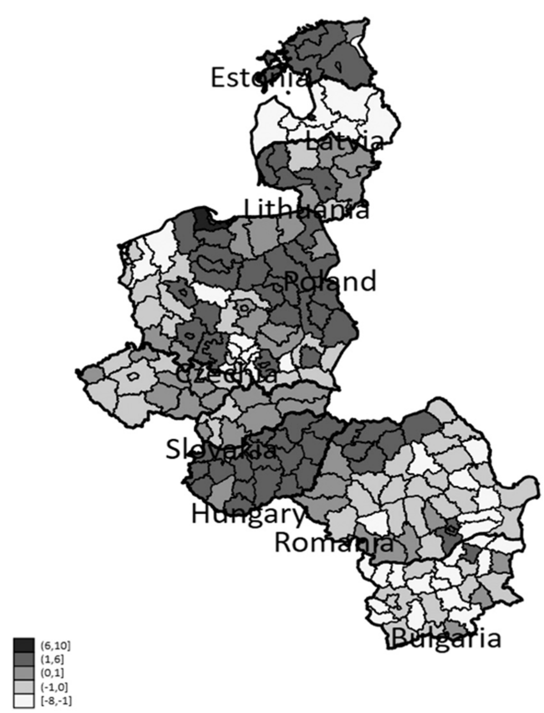

Fig. 2. Recoverability of Regions Compared to the CEE Average (reccee).

factors. Second, they ignore other phenomena, including long-run trends in regional populations, secular structural changes, etc. Third, a fixed-length period recovery provides a slightly different perspective on the recovery, and it is also a more useful tool to be applied to our post-COVID19 shock simulations. In the analysis below we account for these shortcomings.

4. Specification of the model

Anselin (1988) developed spatial regression model where a spatial lag of the dependent variable as well as a spatial lag of the independent variable matrix are added to the set of explanatory variables. The model, known as the Spatial Durbin Model (SDM), in its structural form can be written as:

$$\boldsymbol{y} = \boldsymbol{\alpha}\mathbf{i} + \boldsymbol{\rho}\boldsymbol{W}\boldsymbol{y} + \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{W}\boldsymbol{X}\boldsymbol{\gamma} + \boldsymbol{\varepsilon} \tag{5}$$

where the $\boldsymbol{y}$ is the n x 1 dependent variable vector, $\boldsymbol{\alpha}$ denotes the intercept coefficient, $\boldsymbol{X}$ is the n x p matrix of p independent variables matrix and $\mathbf{i}$ is the n x 1 vector of ones, $\boldsymbol{\rho}$ denotes the spatial autoregressive term, $\boldsymbol{\beta}$ is a p x 1 vector of coefficients capturing the impact of the independent variables on the dependent variable, while $\boldsymbol{\gamma}$ is a p x 1 vector of coefficients for the spatially lagged independent variables. $\boldsymbol{W}$ is the row-normalized contiguity matrix, and $\boldsymbol{\varepsilon}$ is the error term. In this specification, the economic performance of a region depends on its own economic characteristics, on the economic performance of neighboring regions and on the economic characteristics of neighboring regions.[3] LeSage and Fischer (2008) discuss two additional spatial models that are nested within the SDM model, namely, the spatial autoregressive (SAR) model (when $\boldsymbol{\gamma}$=0 and $\boldsymbol{\rho} \neq 0$) and the spatial error (SEM) model (when $\boldsymbol{\gamma} - \boldsymbol{\beta}\boldsymbol{\rho} = 0$).

In this paper we follow the approach outlined by LeSage and Pace (2009), who suggest that the SAR model should be first tested against its non-spatial counterpart, estimated by means of OLS. If the $\boldsymbol{\rho} = 0$ hypothesis is rejected, than the SDM model should be estimated first because it is the only model that yields unbiased coefficient estimates, even if the true data-generation process is of a different form, e.g. SAR or SEM. SDM is also the only model that produces both global and local spillover effects and, related to that, it does not impose prior restrictions on the magnitude of these effects (Elhorst, 2010). However, while the SDM yields unbiased parameter estimates because it is a generalization of the SAR and SEM models, testing for the above parameter restrictions and selecting the optimal model can improve efficiency of the estimates. Consequently, it is of some value to select the correct type of spatial model.

Once the correct model is chosen, LeSage and Pace (2009) recommend estimating the direct, indirect, and total effects for each independent variable. The direct effect captures the impact of explanatory variables in region i on the dependent variable in region i. The indirect effect represents the spillovers from related regions. How these effects are measured is discussed below.

5. Data

The data used in this study refer to NUTS-3 statistical regions in nine Central and Eastern European Countries, Bulgaria, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, and Slovakia. The main source of data is Eurostat, but, in some cases, national sources, most notably the Polish Local Database, BDL from the Central Statistical Office, GUS (https://bdl.stat.gov.pl/), were also used for missing observations. Eurostat also provided the spatial data in the form of shapefiles with geographical coordinates, which are used in the article for the purpose of tracking spatial dependency and spillovers. While we make use of the temporal information to capture the impact of pre- and post-crisis regional features on regional resistance and resiliency to the crisis, as well as the role of post-shock adjustments for the recovery, the models themselves are cross-sectional over the 199 NUTS-3 regions in our sample.

Regional resistance is calculated by estimating the trend non-agricultural employment, $y_{i,\ t}$, in order to control for long-run tendencies in regional employment associated with long-term outward or inward migration, demographic change and economic transition processes:

$$y_{i,t} = a + bt + ct^2 + \in_t \tag{6}$$

where $y_{i,\ t}$ is expressed in logs. Next, we calculate the differences between pre-crisis peak and trend employment and between crisis trough and trend. Resistance is defined as the difference between the latter and the former. Recoverability is defined as the increase of the cyclical component of employment in the 2-year period following the trough.

In line with previous studies, we consider explanatory variables that capture regional economic structures, proxied by shares of employment in industry and the dynamics of structural change. Structural changes that occur shortly before the outbreak of the crisis can generate fragility in the regional economy because new firms lack the financial resources and integration into supply networks needed to weather the crisis as well as can more established firms. As for recoverability, we want to check whether, according to the hypothesis proposed by Martin and Sunley (2015), regional economies that adapt their structure in response to the shock recover more effectively.

To measure structural change, we use a modified Lilien index (*mli*) of structural change between two points in time (t_0 and t_1) as an explanatory variable in our resistance and recoverability equations (Lilien, 1982; Mussida & Pastore, 2012). The index is defined for each region i as:

$$mli_i = \sqrt{\sum\left(\bar{b}_{ijT}\right) \times \left\{ln\left(b_{ijt_1}/b_{ijt_0}\right) - ln\left(B_{it_1}/B_{it_0}\right)\right\}^2} \tag{7}$$

where.

b_{ijt1} = non-agricultural employment in region i, sector j, time t_1.

B_{it1} = total non-agricultural employment in region i, time t_1.

$\bar{b}_{ijT}$ = average share of sector j in total regional employment in region i in the period between t_0 and t_1.[4]

The index is a measure of temporal dispersion. It takes the value of zero if no structural changes occurred between t_0 and t_1, while higher values are associated with larger structural shifts. The advantage of this index, as opposed to the original Lilien index, is that it enables the structural change between two periods to be independent of the time sequence and it accounts for the weight (size) of the sectors. The *mli* index is calculated for the pre-crisis period over the years 2005–2007. For the crisis period, starting in 2008, we estimate crisis-period *mli* indices over 2-year, 3-year and 4-year windows and find that the 4-year window has the greatest explanatory power.

Table 2, which reports the summary statistics, shows that the *mli* for the latter periods were much smaller than for the pre-crisis period, evidently because structural change requires new investments, and

[3] The error term, $\boldsymbol{\varepsilon}$, has a zero mean and constant variance and is independently and identically distributed.

[4] There are 6 sectors, based on the NACE classification. These are Agriculture, forestry and fishing (A); Industry (except construction) (B-E); Construction (F); Wholesale and retail trade, transport, accommodation and food service activities, information and communication (G-J); and Financial and insurance activities, real estate activities, professional, scientific and technical activities, administrative and support service activities (K-L); Public administration and defense, compulsory social security, education, human health and social work activities, arts, entertainment and recreation, repair of household goods and other services (M-T).

Table 2
Summary statistics.

Variable	Description	Mean	S.D.	Min	Max	Moran's I Statistic Cross-border Spillovers	No Cross-border Spillovers
Resistance		−0.136	0.055	−0.372	−0.039	149.90*	514.31*
Recovery		0.039	0.032	−0.018	0.188	38.42*	31.25*
Min	Maximum negative distance of the employment cyclical component from the trend during the crisis	−0.044	0.029	−0.166	0.011	102.49*	72.01*
	Modified Lilien Index from:						
mli0507	2005 to 2007	1.103	0.659	0.272	4.753	110.82*	95.43*
mli0810	2008 to 2010	0.343	0.466	0.003	3.000	73.39*	80.59*
mli0811	2008 to 2011	0.296	0.401	0.002	2.824	32.61*	36.34*
mli0812	2008 to 2012	0.360	0.413	0.001	2.052	136.71*	148.31*
Density	Population density in 2007, 100 inhabitants/km^2	2.273	7.987	0.140	84.89	0.21	0.22
Industry Share	Share of employment in industry, 2007	0.255	0.076	0.085	0.445	79.15*	70.10*
Decline period	Num. of years from pre-crisis peak TO mid-crisis trough	3.840	1.299	1	7	35.95*	45.06*

* indicates statistical significance at the 1% level.

investment activity fell sharply during the crisis. Firm failures and the general contraction of economic activity during the crisis were sufficiently generalized so that changes in regional economic structures were smaller than the structural changes fueled by the economic boom that occurred in CEE prior to the crisis (Brada & Slaveski, 2012). Although, overall, the crisis inhibited structural changes in economic activity in the regions, the summary statistics for the *mli* show that some regions did achieve significant structural changes in their economic activities.

Additionally, we control for population density, which may be a proxy for agglomeration economies, and for proximity to "old", i.e., pre-2004, EU member states, by including a zero-one dummy variables for regions bordering with old EU member countries to see if proximity to these countries had some effects on CEE regions.[5] Summary statistics for the dependent and explanatory variables are reported in Table 2. All variables exhibit considerable variability over the 199 NUTS 3 regions, reflecting the regional heterogeneity of CEE as well as spatial dependence.

In order to check for the existence of spatial dependence or clustering in our data, we introduce row-normalized contiguity spatial weighting matrices ($\boldsymbol{W}$), containing ones, $\boldsymbol{w}(i,m)$, for contiguous regions i and m and zero otherwise. We use one matrix that allows for cross-national border regional spillovers among the sample countries as well as one that excludes such a possibility. Allowing for cross national border spillovers means that a region in one of our sample countries could be affected by developments or characteristics in an adjacent region in another sample country. If we do not allow such cross-border effects, then only regions within a given country can affect each other through spillovers. Separately, as we explain above, we also allow for the possibility that adjacency to a region in an "old" EU member country involves some form of spillover, which potentially could be important because the "old" EU members were less severely affected by the crisis. Clearly, the possibility of some spillovers between regions within a country is to be expected. Firms and workers can move from one region within a country to a neighboring region in the same country with relative ease. Movements between regions in two different countries, even if they are contiguous, may be more difficult due to legal, transportation and language barriers. Nevertheless, membership in the EU could have reduced such barriers to cross-country spillover effects. The $\boldsymbol{W}$ matrices enable us to investigate spatial autocorrelation, and they are also necessary for spatial regression effects, should the former be detected.

We test for the existence of spatial autocorrelation by using Moran's I test, which employs the I statistic:

$$I = \frac{N}{\sum_i \sum_m w(i,m)} \frac{\sum_i \sum_m w(i,m)[(x_i - \bar{x})(x_k - \bar{x})]}{\sum_i (x_i - \bar{x})^2} \tag{8}$$

where N is the number of regions (indexed by i and m) and x is the variable of interest. The null hypothesis is that the data are randomly distributed across regions. We report the p-values for the Moran's I spatial autocorrelation statistic in Table 2. Based on these results, it is clear that the spatial distribution of variables in the dataset is more spatially clustered than would be expected if the underlying spatial processes were random. The only exception to this is the variable population density.

6. Estimates

Following LeSage and Pace (2009) and Elhorst (2009), the starting points of our empirical exercise are the non-spatial equations for resistance and recoverability. Since the $\boldsymbol{\rho} = 0$ hypotheses are comfortably rejected by means of the Anselin (1988) LM-test in both cases (see Tables 3 and 4), we subsequently test SDM models against the more parsimonious SAR versions.

In the case of resistance our procedure suggests that the SDM model is most appropriate, while in the case of recoverability, SAR leads to most unbiased and efficient estimates. Hence, in the case of resistance, Eq. (5) in the reduced form can be rewritten as:

$$\boldsymbol{y} = (\boldsymbol{I} - \rho \boldsymbol{W})^{-1}(\alpha \mathbf{i} + \boldsymbol{X\beta} + \boldsymbol{WX}\gamma + \boldsymbol{\varepsilon}) \tag{9}$$

This transformation enables us to calculate partial derivatives of $\boldsymbol{y}$ with respect to each of the k-th explanatory variable as:

$$\begin{bmatrix} \frac{\partial y_1}{\partial x_{1k}} & \cdots & \frac{\partial y_1}{\partial x_{nk}} \\ \vdots & \ddots & \vdots \\ \frac{\partial y_n}{\partial x_{1k}} & \cdots & \frac{\partial y_n}{\partial x_{nk}} \end{bmatrix} = (\boldsymbol{I} - \rho \boldsymbol{W})^{-1} \begin{bmatrix} \beta_k & \cdots & \boldsymbol{w}_{1n}\gamma_k \\ \vdots & \ddots & \vdots \\ \boldsymbol{w}_{n1}\gamma_k & \cdots & \beta_k \end{bmatrix} \tag{10}$$

LeSage and Pace (2009) and LeSage and Dominguez (2012) show that the coefficients of the spatial models cannot be interpreted as if they were simple partial derivatives, which is also evident from Eq. (10). Consequently, we calculate direct and indirect spillover effects. Golgher and Voss (2016) show that using a row-normalized contiguity weight matrix, direct and indirect effects in the SDM model are given by:

[5] Less than 10% of the regions in our sample bordered an old EU member. We also controlled for regional productivity, education levels, innovativeness and urbanization, but these variables turned out to be insignificant in every specification.

Table 3
Estimation results - resilience.

	OLS (1)	OLS (2)	SDM Generalized Spatial 2SLS (3)	SDM Generalized Spatial 2SLS (4)
mli0507	−0.0405***	−0.0136**	−0.0166**	−0.0162**
	[−5.90]	[−2.12]	[−2.55]	[−2.41]
Pop Density	0.334	0.512***	0.348*	0.428**
	[0.92]	[2.95]	[1.93]	[2.46]
industry share	0.133***	0.0600*	0.0483	0.0485
	[2.83]	[1.81]	[1.39]	[1.41]
old EU dummy	0.0293***	0.0106*	0.00624	0.0083
	[2.68]	[1.78]	[0.97]	[1.33]
Intercept	−0.129***	−0.134***	−0.132***	−0.137***
	[−8.27]	[−8.38]	[−7.14]	[−7.82]
W*				
mli0507			0.0356**	0.00557**
			[2.48]	[2.26]
Density			1.804*	0.133
			[1.80]	[0.64]
industry share (γ)			0.0331	0.00657
			[0.71]	[0.77]
resistance ($\boldsymbol{\rho}$)			0.381***	0.0541**
			[3.14]	[2.41]
Country effects	NO	YES	YES	YES
Cross-border spillovers	–	–	Allowed	Not allowed
N	199	199	199	199
R^2	0.322	0.619		
Pseudo R^2			0.621	0.625
	Test p-values:			
Anselin LM (χ^2)	[0.00]	[0.00]		
$\boldsymbol{\gamma} = 0$			[0.00]	[0.00]
$\boldsymbol{\gamma} - \boldsymbol{\beta\rho} = 0$			[0.00]	[0.00]
	direct effects			
	mli0507		−0.015**	−0.015**
			[−2.23]	[−2.22]
	Density		0.469**	0.470***
			[2.37]	[2.61]
	industry share		0.052	0.051
			[1.49]	[1.49]
	indirect effects			
	mli0507		0.036*	0.027*
			[1.85]	[1.81]
	Density		2.375*	0.895
			[1.72]	[0.73]
	industry share		0.063	0.053
			[1.01]	[0.99]

Notes: Anselin LM - H_0: Spatial Lagged Dependent Variable has No Spatial Autocorrelation.
*, **, *** denote significance at the 10%, 5% and 1% level respectively.

$$direct = \frac{3-\rho^2}{3(1-\rho^2)}\beta_k + \frac{2\rho}{3(1-\rho^2)}\gamma_k \quad (11)$$

$$indirect = \frac{3\rho+\rho^2}{3(1-\rho^2)}\beta_k + \frac{3+\rho}{3(1-\rho^2)}\gamma_k \quad (12)$$

The indirect effects in our model can be divided into two parts: the local effects, due to the γ_1 coefficient, and the global effects, arising from the $(\boldsymbol{I}-\rho\boldsymbol{W})^{-1}$ matrix. Local effects are local because their impact is only on immediate neighbours. Global spillovers affect all regions, because they include feedback effects that arise as a result of impacts passing through neighboring regions and returning to the region from which the change originated.

For recoverability, Eq. (5) is simplified to the following SAR model:

Table 4
Estimation results - recoverability.

	OLS (1)	OLS (2)	SDM Generalized Spatial 2SLS (3)	SDM Generalized Spatial 2SLS (4)
Min	−0.641***	−0.472***	−0.557***	−0.598***
	[−5.91]	[−4.33]	[−5.29]	[−5.64]
decline period	0.004***	0.005***	0.004***	0.004***
	[2.63]	[3.66]	[2.81]	[2.82]
industry share	−0.000	0.014	−0.007	−0.007
	[−0.02]	[0.74]	[−0.32]	[−0.32]
mli0812	0.016***	0.011***	0.014***	0.013***
	[4.03]	[2.98]	[3.61]	[3.25]
Old EU dummy	0.001	−0.002	0.005	0.004
	[0.28]	[−0.43]	[0.96]	[0.78]
Intercept	−0.010	−0.007	−0.020**	−0.018*
	[−0.87]	[−0.69]	[−2.00]	[−1.76]
W*				
Recovery			**0.467*** **	**0.422*** **
			[3.35]	**[3.34]**
Country effects	NO	YES	YES	YES
Cross-border spillovers	–	–	Allowed	Not allowed
N	199	199	199	199
R^2	0.308	0.430		
Pseudo R^2			0.464	0.467
	Test p-values:			
Anselin LM (χ^2)	[0.00]	[0.00]		
$\boldsymbol{\gamma} = 0$			[0.11]	[0.13]
$\boldsymbol{\gamma} - \boldsymbol{\beta\rho} = 0$			[0.00]	[0.00]
Wald test of spatial terms (χ^2)			[0.00]	[0.00]
	direct effects			
	Min		−0.578***	−0.614***
			[−5.46]	[−5.77]
	decline period		0.004***	0.004***
			[2.86]	[2.85]
	industry share		−0.007	−0.007
			[−0.32]	[−0.32]
	mli0812		0.014***	0.013***
			[3.71]	[3.32]
	indirect effects			
	Min		−0.363**	−0.278**
			[−1.99]	[−2.22]
	decline period		0.003*	0.002
			[1.84]	[1.94]
	industry share		−0.004	−0.003
			[−0.29]	[−0.30]
	mli0812		0.009**	0.006**
			[1.98]	[2.27]

Notes: see Table 3.

$$\boldsymbol{y} = \alpha\mathbf{i} + \rho\boldsymbol{W}\boldsymbol{y} + \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \quad (13)$$

or, in the reduced form:

$$\boldsymbol{y} = (\boldsymbol{I}-\rho\boldsymbol{W})^{-1}(\alpha\mathbf{i} + \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}) \quad (14)$$

The partial derivative of y with respect to k-th independent variable can be computed as:

$$\begin{bmatrix} \frac{\partial y_1}{\partial x_{1k}} & \cdots & \frac{\partial y_1}{\partial x_{nk}} \\ \vdots & \ddots & \vdots \\ \frac{\partial y_n}{\partial x_{1k}} & \cdots & \frac{\partial y_n}{\partial x_{nk}} \end{bmatrix} = (\boldsymbol{I}-\rho\boldsymbol{W})^{-1} \begin{bmatrix} \beta_k & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \beta_k \end{bmatrix} \quad (15)$$

Finally, direct and indirect effects in the SAR model become (Golgher & Voss, 2016):

$$direct = \frac{\beta_k}{3(1-\rho^2)}\left(3-\rho^2\right) \tag{16}$$

$$indirect = \frac{\beta_k}{3(1-\rho^2)}\left(3\rho+\rho^2\right) \tag{17}$$

while the indirect effects are only global in this model.

In the presence of spatial autocorrelation among both dependent and independent variables, OLS as well as 2SLS estimates are inconsistent and need to be replaced by a better-suited estimation method (Kelejian & Prucha, 2002). Hence, the models are estimated using the spatial two-stage least squares method, which is both consistent and relatively efficient in our sample.

Table 3 contains estimation results for the resistance equations. We start with the OLS estimates (Columns 1 and 2), pooled and without and with country fixed effects. These estimates assume no spillovers between regions, whose resilience and recoverability are thus assumed to depend only on their own characteristics. The Anselin LM strongly rejects the null hypothesis of no spatial autocorrelation in the dependent variable. We therefore estimate the full SDM model with spatial lags of both dependent and independent variables using generalized spatial 2SLS. Column 3 provides estimates when cross-border spillover effects among CEE countries are allowed, and column 4 reports results if cross-border spillover effects are not allowed. The effects of allowing cross-border effects or not are minor with respect to the parameter estimates for a region's own characteristics.

First, we discuss the direct effects. The direct effect for the variable x_k (on y) shows the impact of unit increase in x_k in a given region on y in the same region (averaged over all regions). Structural change before the crisis, *mli0507*, has a negative and significant effect on resilience as expected. Population density, on the other hand has a positive effect on resilience, reflecting the contribution of strong economies of agglomeration to resistance. The coefficients for industry's share in regional employment is not significant. The insignificance of the coefficient for contiguity to an "old" EU member country suggests the economic integration between old and new EU member countries was an incomplete project as contiguous regions of CEE and the old EU had limited economic spillovers at the time of the crisis. Given that the earliest that some of the CEE countries joined the EU was 2004 and others joined even later, this is not surprising.

The indirect effect for the variable x_k on y indicates the impact of unit increase in x_j in a given region on y in all other regions jointly, averaged over the regions where the impulse can potentially occur. For the indirect effects, *mli0507* has a positive effect on resilience, but the impact is marginal at the 10% level. Population density has a positive but marginally significant effect at the 10% level only when we allow cross border effects. Industry's share in employment is statistically insignificant. Overall, we find that the direct effects of structural change before the crisis and population density are relatively larger than the indirect effects.

The spatial autoregressive term (ρ) measures the strength of spatial dependence, i.e. an effect that will be exerted on y in a given region following a unit change of y in all other regions. There are bigger differences between Columns 3 and 4 with respect to the size of the estimates of the spatial parameters. The Wald test reported in Columns 3 and 4 confirms the joint significance of spatial terms as they are significant at the 1 and 10% significance levels depending on whether cross-border spillovers are allowed or not. Structural change before the crisis, *W*mli0507,* in adjacent regions improves resistance in region i, perhaps because as fragile new firms in adjacent regions go out of business, more established rivals in region i can absorb their customers and workers. The ρ coefficient (W**resistance*), the resistance in adjacent regions, is significant and positive showing that resistance is spatially dependent. The resistance coefficient when cross-border spillover effects are not allowed is 0.0541, so, from the perspective of a region i, if resistance in an adjacent region increased, then 5.41% of this increase would be transmitted into region i. Consequently, it is helpful to be a region surrounded by resilient regions. When we allow for cross-border spillover effects among the CEE countries in our sample, the resistance spillover to region i goes up to 38.1%, which suggests very strong spillover effects, indicating the importance of cross-border spillovers in achieving resistance.

Table 4 presents estimation results for the recoverability equations. The Anselin LM test in all cases strongly rejects the null hypothesis that the spatial lagged dependent variable has no spatial autocorrelation, and the Wald test confirms the joint significance of spatial terms regardless of whether cross-border spillovers are allowed or not. In terms of the direct effects, several own-region characteristics have significant coefficients that do not differ much whether cross-border effects are allowed or not. The length of the decline period has a positive effect, suggesting that the longer a region has to adjust to a shock, the faster will be its recovery. This is also true of its ability to change its employment structure at the beginning of the crisis as the positive coefficient for *mili0810* indicates. However, the size of the estimated coefficients for each variable indicates that the economic significance of the ability to change employment structure is greater than having a longer period to recover. These results suggest that economic reforms and policies providing aid to regions in crisis to support greater structural transformation can be useful ways to promote recoverability of regions.

Regional economic structures measured in terms of employment share in industry do not have a significant direct effect on recoverability. As in the case of the resistance equation, the old EU dummy variable is insignificant. Regarding indirect effects, the two variables that are statistically significant, both with negative effects, are the min variable showing the maximum negative distance of cyclical employment from its trend during the crisis and, *mli0812*, employment structure change. The first coefficient suggests that the larger the shock to employment, the more difficult is the recovery; the second suggests that much of the observed structural change may be due to the disappearance of firms that existed in the pre-shock period. *Decline period,* meaning the length of the decline, is marginally significant only when allow cross-border spillovers. Again, the direct effects are larger than the indirect ones.

Turning to the effects of the characteristics of adjacent regions, the recoverability coefficient (ρ) in case of cross-border spillover effects not allowed is 0.467, so, from the perspective of region i, a 1 percentage point higher recoverability in adjacent regions brings a 0.467 percentage point increase in recoverability in region i. When we allow for cross-border spillover effects, this increase becomes smaller, 0.422 percentage points. These results suggest that, as one would expect, a region surrounded by recovering regions will recover more quickly and the spillovers are quite large.[6]

In sum, our results show that there is significant clustering of similar economic regions both within CEE countries and even across the borders of the sample countries. Moreover, there are important spillover effects between regions both from the economic outcomes they generate and also from their economic characteristics. How these findings can be informative in predicting the region's recovery from the effects of the COVID-19 pandemic is the subject of the next section.

7. Lessons for recovery from the COVID 19 pandemic

We use the estimated coefficients from our recovery equation to stimulate the impact of COVID-19 on our regions. The independent variables in this equation are min, *decline period*, *industry share*, *mli0812*

[6] Our results mirror those of Petrakos and Psycharis (2016) for the regions of Greece during the financial crisis.

Table 5
Simulation scenarios under different assumptions.

Scenario	decline period (years)	4-year modified Lilien index
1	1	0
2	2	0
3	3	0
4	1	same as *mli0812*
5	2	same as *mli0812*
6	3	same as *mli0812*
7	1	1.5* *mli0812*
8	2	1.5* *mli0812*
9	3	1.5* *mli0812*

and *old EU* dummy. To calculate the simulated values of the dependent variable, recovery of industrial employment, we need to make some assumptions about these variables. We use *min,* the cyclical deviation from the trend in industrial employment in a region to introduce a shock to economic activity by assuming a 10% deviation of the cyclical employment from its trend.[7] *Industry share* is recalculated on the newest available data (i.e. 2017). *Old EU* is the same as it was during the 2008 crisis. The remaining two independent variables, *decline period* and the employment structure change *Lilien index*, are assumed to change, creating 9 scenarios as indicated in Table 5. Thus, in our simulation, we do not attempt to model the time path of the pandemic but rather vary parameters related to its time path and effects. This avoids problem of trying to forecast the effect of "pandemic surprises" such as the upsurge of COVID-19 infections in CEE in late 2020.

In our scenarios, the decline period is allowed to vary from one to three years. The longer the period over which a decline in industrial employment occurs, the easier it should be for a region to recover. Structural changes in industrial employment are assumed to follow one of three patterns. In the first case, we assume that the Lilien index does not change from what it was in the pre-shock period. Second, we assume that the Lilien index changes by the same amount as was observed during the post-financial-crisis period. Finally, we assume that the structural change would be 1.5 times as large as that experienced in the aftermath of the financial crisis.

The simulation results are reported in Table 6 with and without cross-border spillovers allowed. The results are qualitatively the same, suggesting that cross-border effects do not affect the recovery period in a major way. Table 6 reports the number of regions that fully recover after 2 years under 9 different scenarios. Assuming no change in the Lilien index yields simulation results that show that no region can achieve full recovery after 2 years regardless of the length of the period of decline (i.e., scenarios 1–3). This finding stresses the importance of changes in the structure of economic activities on recoverability. Allowing a one-time change in the Lilien index and keeping it at the same level as *mli0812,* the post-financial crisis period value, and varying the decline period from 1 to 3 years (scenarios 4–6) produces 2, 7 and 9 regions fully recovered after 2 years, respectively, showing the combined positive effects of greater structural change and a longer period to adjust to the decline caused by the shock. Increasing the Lilien index by 50% and allowing the decline period to increase from 1 to 3 years over time (scenarios 7–9) yields an even higher number, 12, 21, and 31, of fully recovered regions after 2 years, showing the importance of employment structural changes in achieving recoverability. Nevertheless, even the most optimistic scenario shows only 31 out of 199 regions fully recovered from the employment shock caused by the CORONA-19 shock after two years of recovery, meaning that under our scenarios, the effects of the pandemic on employment are likely to be long lasting for the

[7] This may have seemed a high value given that COVID-19 infection rates were relatively low in CEE in early 2020. However, a "second wave" of the pandemic struck many more people in the region in late 2020, and the 10% decline may well serve as an appropriate, if conservative, scenario.

Table 6
Summary of simulation results.

Scenario	Mean recovery	Standard deviation	Min	Max	Number of regions which fully recover after 2 years
Cross-border spillovers allowed					
1	0.066	0.010	0.043	0.091	0
2	0.073	0.011	0.048	0.101	0
3	0.080	0.012	0.053	0.110	0
4	0.074	0.014	0.045	0.124	2
5	0.081	0.015	0.050	0.133	7
6	0.088	0.016	0.055	0.142	19
7	0.078	0.017	0.046	0.143	12
8	0.085	0.018	0.051	0.153	21
9	0.092	0.019	0.055	0.162	31
No cross-border spillovers allowed					
1	0.071	0.009	0.049	0.095	0
2	0.077	0.010	0.054	0.104	0
3	0.084	0.011	0.059	0.113	1
4	0.078	0.013	0.051	0.123	2
5	0.085	0.013	0.056	0.131	7
6	0.091	0.014	0.060	0.140	19
7	0.081	0.015	0.052	0.140	11
8	0.088	0.016	0.056	0.148	21
9	0.095	0.017	0.061	0.157	31

majority of regions. Overall, our results indicate that regions with a longer period to adjust to a shock and with the ability to implement structural changes in employment structure are more likely to recover.

It is also instructive to consider the recovery rates reported by the scenarios. Since the employment shock is assumed to be 10% (0.1), then a full recovery from this shock would require an increase in employment of 11.1% (=0.10/0.9) or 0.111 in Table 6. The mean values for regions' recovery are all less than 0.111, meaning that, overall, industrial employment in CEE does not recover to the pre-pandemic levels within two years of the end of the pandemic. More troubling from the standpoint of policymakers is that the worst performing regions only make up about or less than half of the loss in employment. On the other hand, the

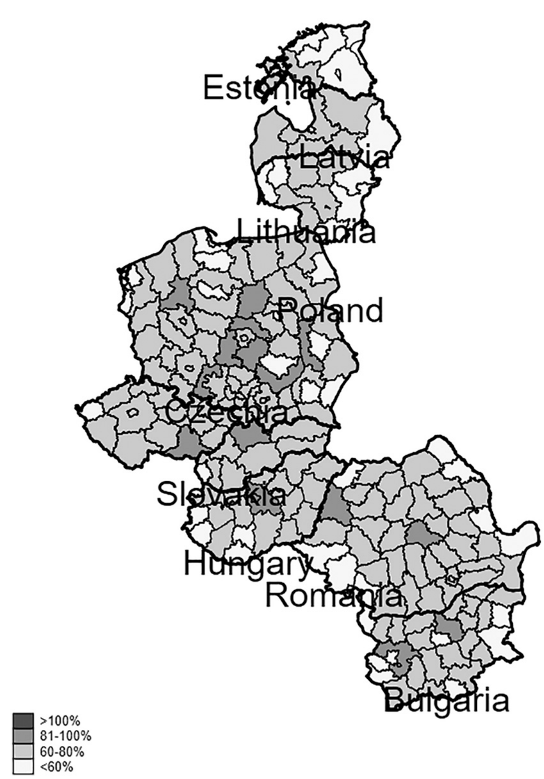

Fig. 3. Regional recovery after 2 years under scenario #2, Lilien Index = 0.

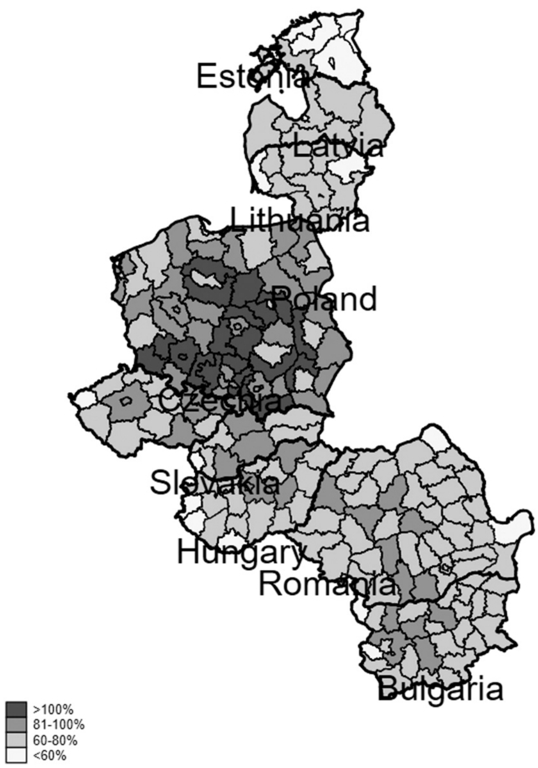

Fig. 4. Regional recovery after 2 years under scenario #8, Lilien index = 1.5 Lilien index of post- financial crisis.

best-performing regions make significant gains in employment under the more optimistic scenarios. Thus, the recovery from the economic effects of the pandemic will create even greater regional disparities in employment and welfare, leading to social and political strains.

An important question is which regions recover more than others. To answer this question, we illustrate the recovery cases under selected scenarios in Figs. 3 and 4. Due to space considerations, we do not map all 18 cases reported in Table 6, but use a 2-year decline scenario, and the scenarios number 2 and 8, which use different assumption for the Lilien index, for illustrative purposes. We report only the maps from the scenarios assuming cross-border spillovers. Since we only have one region (and only in scenario 2) with less than 50% recovery, we use the percentage of recovery after 2 years using the following ranges: <60%, 60–80%, 81–100% and > 100%.

Fig. 3 shows that, with no structural change assumed, the clustering of successful regions is limited to areas of central Poland. Also evident is that many of the regions with the least ability to recover are found on the periphery of each country, particularly on the eastern border.

Fig. 4 shows much greater clustering of successful regions in all but the Baltic states. Thus, structural flexibility is an important source of recoverability and generates important regional spillover effects in all of the CEE countries. The maps show that the greatest recovery takes place in regions of Poland and Czechia. As these countries have diversified their economies more than the others (see Table 1), they have greater opportunities for structural change and thus more regions recovered relative to other countries.

8. Conclusions, policy implications and suggestions for further research

In this paper, we have shown the clustering of highly performing regions in nine CEE countries, both in terms of their ability to react to external shocks and to recover from them. This clustering is due in part to the ability of some regions to alter their economic structure during downturns in economic activity and in part to strong positive regional spillovers, which cause the formation of clusters of high-performing and low-performing areas, a process that exacerbates regional income disparities. This finding suggests that an integrated regional approach is necessary to reduce income disparities in individual CEE countries in their recovery from the pandemic, and, hence, a close coordination of related economic and social policies within these countries would be of significant benefit. Also, EU regional support funds, which play an important role in financing regional policies in CEE should also be directed toward promoting structural change and flexibility.

We use the experience of the post-financial-crisis period to project the recovery of these CEE regions from the effects of the COVID-19 pandemic under various assumptions about the length of the downturn caused by the pandemic and about the ability of regions to adjust their economic structure during the downturn and afterward. We find that such flexibility is an important component to recoverability, and thus policies that promote such structural changes should be an important component of policies designed to lead to the economic recoverability of the region. This is particularly important because our results show further clustering of well and poorly performing regions, and such clustering can lead to social and political unrest due to the differences in the economic fortunes of regions within a country. Given that the recent studies on the pandemic show that its biggest impact is on savings and the poor, people with low income are unlikely to change behavior such as social distancing. Hence, our evidence of growing regional inequalities suggests further challenges for policymakers to slow down the spread of the virus. A recent study of the United States economy by Sharif et al. (2020) finds that the COVID-19 pandemic had a more significant impact on the nation's geopolitical risk level than did its overall economic uncertainty. Hence, the COVID-19 pandemic could have also increased the regional geopolitical risk in CEE countries with negative implications for their financial markets, an interesting research avenue to explore.

A second finding is that recovery from the effects of the pandemic on employment will be slow. After a two-year recovery period, many regions will not have fully recovered the pre-pandemic level of industrial employment. Such slow recovery is consistent with other studies of recovery from pandemics. For example, Brainerd and Siegler (2003) examine the experience of individual states of the United States and find economic effects of the influenza epidemic of 1918–1919 that are still evident in 1930. Correia, Luck, and Verner (2020) also study the same period in the United States and find that negative regional effects from the epidemic make themselves felt quickly and display considerable persistence. This suggests that our results are in general agreement with studies for different countries and causes of shocks, meaning that our finding can apply to other upper- and middle-income countries as well as they do to CEE.

The paper also suggests areas of research on resiliency that deserve further study. The first is the need to add more covariates to the regressions explaining resistance and recovery including "softer" covariates that reflect religious and social mores and behaviors that influence the extent to which the residents of regions are willing and able to respond to shocks in a flexible way (see, e.g., Tabellini, 2010). A second area where research is needed is to endogenize regional structural change in response to shocks by linking it to EU and national regional policy measures and to provide more specific descriptions of regional economies and their links to national and international supply chains.

It is well known that social distancing has been an important policy tool used by policymakers to fight the pandemic and there have been some efforts to predict social distance practices and show that the poor are less likely to do social distancing. However, some countries did not practice social distancing as much as other countries because there have been both policy and social disagreements about its effectiveness. Hence, a third area of research is the role of social distancing practices and different income status at a regional level in affecting the ability of countries to resist and recover from shocks such as COVID-19.

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