

**ORIGINAL ARTICLE**

Territorial resilience on the aftermaths of COVID-19 crisis—An exploratory analysis on the role of innovation

Ana Sargento  | Ana Sofia Lopes

CARME – Centre of Applied Research in Management and Economics, ESTG, Polytechnic of Leiria, Leiria, Portugal

Correspondence

Ana Sargento, CARME – Centre of Applied Research in Management and Economics, ESTG, Campus 2, Polytechnic of Leiria, Morro do Lena - Alto do Vieiro, 2411-901 Leiria, Portugal.
Email: ana.sargento@ipleiria.pt

Funding information

Fundação para a Ciência e a Tecnologia, Grant/Award Number: UIDB/04928/2020

Abstract

This study examines the impact of different regional determinants on heterogeneous territorial resilience to the COVID-19 crisis, highlighting the role of innovation, particularly the engagement of research and innovation (R&I) entities in networks with businesses. Two ordinary least squares (OLS) models were separately estimated for the resistance and the recovery phases, complemented by a multinomial logistic model, applied to test for a nonlinear relationship between R&I networks and territorial resilience. The results are robust concerning the positive influence on municipalities' resistance and recovery of having R&I entities collaborating in innovation consortia. Education, stability, and sectoral diversification of the local labor market are also essential for regions to be able to resist to the crisis but seem not important for recovery. Finally, international trade openness and pre-crisis labor performance penalizes both resistance and recovery from downturns.

KEYWORDS

COVID-19, R&I networks, regional recovery, regional resistance, unemployment

JEL CLASSIFICATION

R10, O30



1 | INTRODUCTION

The COVID-19 crisis has increased unemployment all over the world, with Portugal being no exception. Indeed, the total number of registered unemployed (according to monthly Portuguese Institute of Employment and Professional Training [IEFP] data), during the first year after COVID-19 increased by 16.4% compared with the year before. In the second year, a recovery was observed, with unemployment returning to the pre-COVID-19 unemployment levels in April 2022. However, both resistance and recovery phases were highly geographically uneven, with municipalities such as Castro Verde evidencing rates of change of 85.7%, in contrast with the municipality of Mesão Frio (for example) that observed a reduction in unemployment between 2019 and 2020. From 2020 to 2021, while in the majority of counties a significant reduction was observed, in a few, unemployment continued to grow.

This paper seeks to address this territorial heterogeneity for the Portuguese case and to investigate the relevance of regional factors in explaining differentiated economic resilience to the COVID-19 crisis, specifically focusing on the role of innovation networks.

Departing from the theoretical framework and the vast amount of empirical studies on regional resilience (mostly produced after the 2008–2013 crisis), this paper contributes to the existing literature in three ways. First, it considers innovation-related variables as potential determinants of regional resistance and recovery, which constitutes a novelty in relation to what has been done in empirical studies applied to the COVID-19 crisis. Second, within innovation variables, it introduces a unique variable that expresses the engagement of research and innovation (R&I) entities (such as higher education institutions, technological and research centers) in innovation co-creation with businesses, built upon a comprehensive database on Portuguese Research and Development (R&D) projects developed in consortium. Third, the article extends existing empirical evidence on territorial resilience in face of COVID-19 socioeconomic consequences, by applying a seldom used, highly disaggregated geographical level of analysis (Portuguese municipalities) and by explaining their ability to withstand the crisis impact in two phases of regional resilience: resistance and recovery.

Although this work applies specifically to the Portuguese context in the COVID-19 crisis aftermath, we believe the results are of practical usefulness for worldwide regional policy-makers facing economic shocks, particularly concerning the importance of regional policies that enhance regional innovation ecosystems.

This paper is organized in five sections, including the Introduction. Section 2 provides a brief overview of the literature that is used to sustain the conceptual model applied in this study. The sources and methods used in the empirical application are described in Section 3, with the results presented and discussed in Section 4. Our conclusions and suggestions for future developments are presented in Section 5.

2 | THEORETICAL BACKGROUND

The empirical application carried out in this work stands on the theoretical framework related to regional resilience. A comprehensive explanation of the regional resilience concept is beyond the aim of this paper, since it has been thoroughly discussed, (for instance, in the recent contribution of Sutton & Arku, 2022, but also in Martin et al., 2016 and Martin & Sunley, 2015) and empirically studied, particularly in the years that followed the 2008–2013 recession. Acknowledging that the adverse impact of the crisis was regionally uneven within each country (such as in Angulo et al., 2018; Geelhoed et al., 2021; Kitsos & Bishop, 2018) or across European regions (Cappelli et al., 2021; Crescenzi et al., 2016; Giannakis & Bruggeman, 2020), the main research question addressed by these papers was to find out why some regions were more successful in reacting and recovering to shocks than others.

More recently, when the economic effects of COVID-19 became visible, regional resilience studies gained a new impetus, since it was again obvious that the negative impact was regionally heterogeneous, not only regarding disease spread and mortality, but also on socioeconomic variables such as gross domestic product (GDP) and employment.



Martin et al. (2016) presents regional resilience as a complex and multifactorial process according to which regions are more or less prone to be hit by a given shock (vulnerability), affected by the impact of that shock in the first phase (resistance), the ability to get back to a given pre-shock performance level (recovery) and to adjust its economic structures and adapt to the shock's impact (reorientation), and to assume a renewed growth path (renewal).

Several determinants of regions' distinct resilience behavior along these different phases have been theoretically assessed and empirically tested. These factors may be organized into the following broad categories:

- i. Economic structure, particularly sectorial specialization versus diversification. Although a higher specialization may be associated to competitive advantages and higher productivity gains provided by agglomeration economies, empirical studies applied to the 2008–2013 crisis and to the recent COVID-19 context support the portfolio diversification argument. Accordingly, a higher regional diversification contributes to a higher resilience, since a diversified bundle of industries will most probably exhibit differentiated vulnerabilities to the specific shock that has occurred, allowing resources to be transferred from the most affected industries to the least (Boschma, 2015; Crescenzi et al., 2016; Di Caro, 2017; Geelhoed et al., 2021; Martin et al., 2016; Martin & Sunley, 2015).
- ii. Pre-crisis labor market conditions, namely concerning the predominant type of work contracts and unemployment level. It is expected that regions with a higher percentage of workers with permanent contracts exhibit a lower unemployment increase in crises times (Adams-Prassl et al., 2020; Bachmann et al., 2015; Baussola et al., 2015; Fana et al., 2020; Kartseva & Kuznetsova, 2020). Besides, regions with better-performing labor markets (lower pre-crisis unemployment rates) have been found in the literature to be less resilient to shocks. This result has been attested in several studies, either applied to the 2008–2013 crisis (such as Cappelli et al., 2021, Giannakis & Bruggeman, 2020, 2017, Palaskas et al., 2015), or more recently to the COVID-19 context (Lopes & Carreira, 2022; Lopes & Sargento, 2023) and it indicates that factors contributing to a better-performing labor market are not fully sustainable under an economic downturn.
- iii. Quality of government institutions and supportive policy measures. Institutional context (including the political, legal, and financial system), as well as the economic policy measures taken by decision-makers in face of a crisis, are acknowledged to influence economic activity and, therefore, the regions' ability to react and adapt to negative shocks (Boschma, 2015; Martin et al., 2016).
- iv. Innovation resources, competencies, and capabilities.

Given the specific objective of this paper, the subsequent review highlights the contributions that address the influence of the last category of regional resilience determinants: innovation, particularly, the role of innovation networks.

Regional innovation processes have been associated to an evolutionary perspective of resilience: the notion that regions' performance, when facing a new economic context as a consequence of a given shock, depends not only on their predefined socioeconomic structure, but also on their capacity to adapt and evolve into new growth paths, sometimes implying structural reconfiguration (Boschma, 2015; Martin & Sunley, 2015; Rocchetta et al., 2022). Although the bulk of studies on regional resilience tend to emphasize the role of economic structure (Filippetti et al., 2020), some relevant contributions—mostly applied to the Great Recession (2008–2013) context—have accounted for the influence of innovation and technological-related variables. That is the case, for instance, of Muštra et al. (2020) and Bristow and Healy (2018), which rely on the European Commission's Regional Innovation Scoreboard, and of Filippetti et al. (2020) and Cappelli et al. (2020), that use patents as proxy variables to regions' innovation capacity. These studies have concluded that regional innovation capacity has a positive relationship with regional (NUT II) labor market resilience, under the Great Recession's resistance and recovery phases. Capello and Lenzi (2017) classify European NUT II regions into five regional innovation patterns, concluding that the evolution to more complex and intensive innovation patterns has a positive effect on the regional response to the Great Recession, particularly in the later years of recovery. More recently, Rocchetta et al. (2022) studied regional (EU–NUT II)



employment resilience to the Great Recession, focusing on the role of regional technological profiles, characterized through the use of the European patents' database. These authors conclude that regional resilience is positively influenced by the degree of coherence (proximity across the patent classes) and renewal (entry of a new patent class) in regional technology portfolios.

In the study of regional innovation and its impact on regional resilience, several authors have argued for the importance of understanding regional innovation as an interactive process, encompassing a systemic assessment of innovation resources and capabilities in all actors involved—namely: firms, institutions, R&I entities, and final users—but also considering the networks and collective learning established between them, which enhance the so-called regional stock of social capital (Morgan, 2007; Muštra et al., 2020). Indeed, the way by which several innovation actors and assets interact and collaborate in knowledge exchange is crucial for the whole resilience process of regions, from short to long term (Bristow & Healy, 2018). Moreover, these networks also lead to a broader sense of common trust that makes regions less susceptible to negative shocks, reducing transaction costs (Boschma, 2015; Cainelli et al., 2019; Di Caro, 2017; Rutten & Boekema, 2007).

In such context, R&I entities have been highlighted as fundamental nodes in innovation co-creation networks. Academia (including higher education institutions, research centers, and similar entities) can play an important role in sustaining regional innovation capacity, as long as they actively collaborate with their regional partners, rather than standing as 'cathedrals in the desert' (Raagmaa & Keerberg, 2016; Rutten & Boekema, 2007). The numerous examples of rapid innovation that occurred during the early stages of COVID-19 crisis, including the collaborative R&D efforts to develop the vaccines, but also the cases of innovation co-creation between academia and industry toward local development and production of ventilators, face shields, and masks, clearly illustrate that networks were crucial in responding to the immediate needs and constrains imposed by the pandemic.

However, despite the theoretical attention that has been dedicated to the importance of collaborative knowledge networks and the abundant cases that could be observed in the pandemic context, the role of innovation co-creation networks has not been explicitly considered in empirical studies on COVID-19 resilience, to the best of our knowledge.

Aiming to address this gap, we tried to incorporate this social capital dimension of innovation through the inclusion of an innovative variable that captures the participation of non-business entities of the research and innovation system in innovation co-creation networks involving business partners. Details concerning the construction of such variable, as well as the inclusion of additional relevant control variables, are provided in the subsequent section of this paper.

3 | SOURCES AND METHODS

The COVID-19 crisis was very disruptive, deeply affecting the global economy in 2020 (real annual decrease of 3.3% in GDP) but with a fast recovery, of 5.8%, in 2021.¹ Aiming to distinguish resistance and recovery capability of Portuguese counties, herein three distinct time periods were analyzed:

1. pre-COVID-19 period (from March 2019 until February 2020)—the pre-crisis stage—corresponding to the year before COVID-19 hit Portugal. The cutoff point is March 2020, which was the month when the first case of COVID-19 was found in Portugal and when the first economic lockdown was imposed;²
2. COVID-19 period (from March 2020 until February 2021)—the resistance stage—comprehending the major impact of the pandemic and the associated containment measures;

¹<https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG>.

²This was also the month when unemployment started to increase, even after controlling for the seasonality effect. Thus, this cutoff point complies with both institutional and business cycle arguments to define shocks, presented in Di Caro and Fratesi (2022).



3. post-COVID-19 period (from March 2021 until February 2022)—the recovery stage. At the end of February 2021, the number of COVID-19 cases starts to decrease (to the minimum of the last 6 months), and several restrictive measures were relieved during the following month. Also, in the beginning of March 2021, 10% of the Portuguese population was already vaccinated. These arguments, jointly with the advantage of all the periods having the same length, justify our choice for using February 2021 for the breakdown between the COVID-19 and the post-COVID-19 periods.

3.1 | Dependent variable

Regional resilience has been essentially measured through GDP (e.g., Chen & Groenewold, 2022; Gong et al., 2020; Hu et al., 2022) or labor market-related indicators. The latter—(un)employment outcomes—have the advantages of varying at a slower rate than output during recovery cycles (Geelhoed et al., 2021); being better indicators of the social impact of the crises, often associated to specific characteristics of the labor force composition (Di Caro & Fratesi, 2022; Filippetti et al., 2020; Giannakis & Bruggeman, 2020, 2017; Partridge et al., 2022); and are usually accessible at a monthly basis and with a high geographical disaggregation, which does not happen with GDP or gross value added (GVA)-based indicators (Kitsos et al., 2023). Considering the preceding arguments, in the present paper, regional resistance and recovery is measured through an unemployment-based variable.

Microdata from the Portuguese IEFP was used to determine the number of unemployed in each period. The monthly frequency is a significant strength of this data that allow us to be more specific in defining the beginning and end of periods of crisis and recovery.

Following Cappelli et al. (2021), our first dependent variable, regional resistance to the COVID-19 crisis ($URes_m$, with m denoting the municipality), will be:

$$URes_m = -\log\left(\frac{U_{m,COVID}}{U_{m,pre-COVID}}\right), \quad (1)$$

where $U_{m,COVID}$ is the ratio between individuals that had registered in the IEFP centers during the COVID-19 crisis and total population and $U_{m,pre-COVID}$ is the percentage of individuals that had lost their jobs during the year before COVID-19 hit Portugal.

Regional recovery at the municipality level ($URec_m$) will be computed by using a similar methodology:

$$URec_m = -\log\left(\frac{U_{m,post-COVID}}{U_{m,pre-COVID}}\right) \quad (2)$$

where $U_{m,post-COVID}$ is the percentage of individuals that became unemployed between March 2021 and February 2022.

3.2 | Independent variables

As our main goal was to investigate the importance of R&I networks in regional resilience, we determined a variable that corresponds to the number of R&I entities that collaborate with business entities in innovation-based projects, approved in the period 2017–2019 (in relative terms, by thousand companies)— RIN_n . Information retrieved from the National Innovation Agency open data concerning these innovation-based projects was used to obtain this explanatory variable. This variable was included at the NUT III (n) level because several R&I entities (such as universities) are located and have influence in more than one municipality within the NUT III.



Considering that the research capacity and quality of R&I entities might influence both resistance/recovery and the intensity of collaborative networking (Capello & Lenzi, 2017; Muštra et al., 2020), a variable that measures the quality of the local research centers was also included in the model. To do so, we used the classification attributed by the Portuguese Foundation for Science and Technology to the Portuguese R&I entities. This classification ranks from insufficient to excellent (based on scientific publications, projects, and other innovation outputs), which, for the model's purposes, was transformed into a variable with values between 0 (insufficient) and 4 (excellent). Then, the average of this variable at each NUT III was calculated, corresponding to our variable denoted by R&I quality (RIQ_n).

By considering the literature on regional resilience, a set of municipalities' characteristics (R_m), obtained by matching IEFP data with Statistics Portugal (INE) data, using the municipality identification, was also included in the model, as control variables. Following previous literature, (e.g., Chen & Groenewold, 2022; Giannakis & Bruggeman, 2017), we used pre-crisis variables (2017–2019 average), and thus R_m includes:

- Human capital (percentage of workers with higher education) and R&D researchers (by thousand inhabitants);
- Labor stability (percentage of workers with a permanent work contract);
- Pre-crisis unemployment (percentage of unemployed individuals in total population);
- Population density (total population per km^2);
- International trade openness (percentage of the sum of goods exports and imports in total turnover);
- Sectoral specialization—measured by the Herfindahl–Hirschman Index and sectoral employment distribution (particularly, the weight of employment in the accommodation industry);
- Territorial productive assets—gross fixed capital formation (GFCF) per company and GVA per capita;
- COVID-19 intensity—measured by the average number of COVID-19 cases per 10,000 inhabitants in each municipality.³

Finally, the vector R_m also includes a variable corresponding to the transparency index of local government institutions. This index, available for all the Portuguese municipalities, is computed by considering local government performance on 76 indicators distributed by seven dimensions, including the accountability of information on public expenses and revenues, public contracts, and the relation between public service and society (<https://transparencia.pt/itm/>). Higher values of this index indicate more open, responsible, and participatory governance. Thus, this index was included in the model to control for the quality of government institutions that might be related with both R&I networks and regional resilience.

3.3 | Estimation models

First, an ordinary least squares (OLS) model was estimated to investigate the effect of each variable presented above in Portuguese territorial resistance:

$$URes_m = \alpha RIN_n + \beta RIQ_n + \gamma R_m + u_i, \quad (3)$$

where u_i denotes the error term, and α , γ , and β are the parameters to be estimated.

Next, the same set of explanatory variables was used to estimate a model where the dependent variable is $URec_m$:

³This variable was included in the model considering the particularities of COVID-19 crisis that was caused by the pandemic situation and the measures that governments were forced to impose to contain the disease.



$$URec_m = \beta RIN_n + \theta RIQ_m + \rho R_m + v_i. \quad (4)$$

Finally, and to consider the possibility of a nonlinear relationship between R&I networks and regional resistance and recovery, an alternative model was used, following Faggian et al. (2018) and Muštra et al. (2020). The dependent variable (y_m) was obtained by classifying municipalities into four possible groups: (a) low resistance/slow recovery municipalities ($y_m = 0$), (b) low resistance/fast recovery municipalities ($y_m = 1$), (c) high resistance/slow recovery municipalities ($y_m = 2$), and (d) high resistance/fast recovery municipalities ($y_m = 3$). Herein, low resistance is attributed to regions where $URes_m$ is below the country average (which means that unemployment increased more in the municipality than the national average) and slow recovery, to municipalities with a recovery capacity below the average.

The dependent variable was estimated by a multinomial logistic model with competing risks. According to Wooldridge (2010), the probability of a municipality to belong to group k (with $k = 1, 2$ or 3) will be:

$$\Pr(y_m = k|x) = \frac{e^{x\delta_k}}{1 + \sum_{j=1}^3 e^{x\delta_j}}, \quad (5)$$

with x being a vector that includes all the explanatory variables included in Equations (3) and (4). Considering that each municipality has only one value to y_m , the probability of a municipality to belong to the base group ($y_m = 0$, low resistance/slow recovery municipalities) is:

$$\Pr(y_m = 0|x) = 1 - \frac{\sum_{j=1}^3 e^{x\delta_j}}{1 + \sum_{j=1}^3 e^{x\delta_j}} = \frac{1 + \sum_{j=1}^3 e^{x\delta_j} - \sum_{j=1}^3 e^{x\delta_j}}{1 + \sum_{j=1}^3 e^{x\delta_j}} = \frac{1}{1 + \sum_{j=1}^3 e^{x\delta_j}}. \quad (6)$$

Therefore, the probability of a municipality to belong to a certain group ($k = 1, 2$, and 3) compared with the probability of belonging to the base group will be given by:

$$\frac{\Pr(y_m = k|x)}{\Pr(y_m = 0|x)} = e^{x\delta_k}, \quad (7)$$

which, by taking the log transformation, will establish a linear relation with the explanatory variables.

This alternative methodology (multinomial logistic model) has the disadvantage of not using all the information on the resistant/recovery capacities, which is available only when these variables are included in its continuous form. For example, in the multinomial logistic model, it is not possible to distinguish between municipalities with a resistance capacity slightly above the country average from those that are significantly above the average. On the other hand, this modulation establishes a very interesting relationship between the two stages of resilience, thus complementing the results and conclusions obtained by estimating Equations (3) and (4).

4 | RESULTS AND DISCUSSION

4.1 | Regional heterogeneity in unemployment

The number of individuals registered in the IEFP centers in each month of the three periods considered above: pre-COVID-19, COVID-19, and post-COVID-19 are shown in Figure 1. The COVID-19 period line is always above the pre-COVID-19 period, except during the month of January, where the 2021 value is slightly below the value presented in 2020. It is also observed that the most critical month in terms of unemployment was April 2020, where the number of registrations in IEFP centers reached a peak of 63.626 individuals. We note that this was the month right

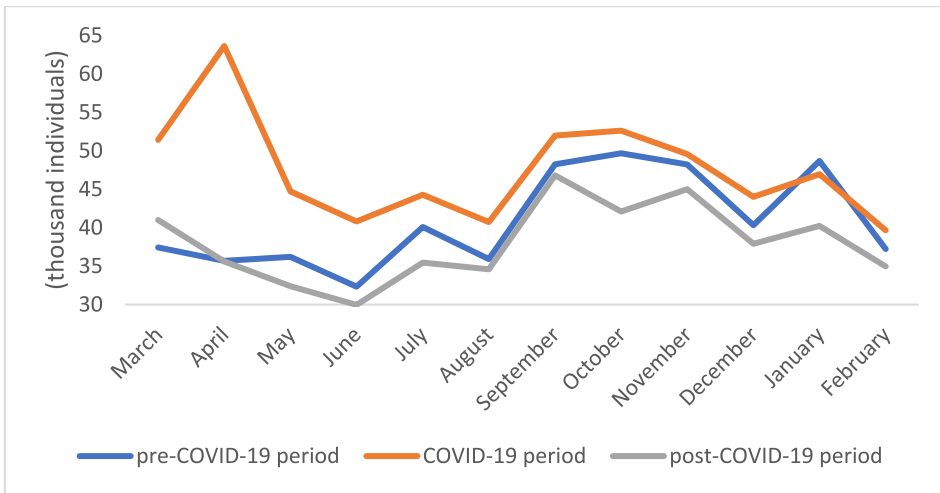


FIGURE 1 Number of registered unemployed (Institute of Employment and Professional Training [IEFP] data).

after the beginning of the economic lockdown and before the Portuguese government put into place several measures to protect the economy (and employment) from the lockdown.

Also, according to Figure 1, the post-COVID-19 seems to be a recovery period, since the corresponding line is always below the COVID-19 period and, notably, also below the pre-COVID-19 (with the exception of March 2021). Finally, the seasonal effect is similar between the three periods with the exceptions of the months of March and April 2020.

4.2 | Descriptive statistics

In Table 1, we provide information on the summary statistics for the variables included in the models. The summary statistics are separately presented for the four groups of municipalities: low resistance/slow recovery (in column 1), low resistance/fast recovery (column 2), high resistance/slow recovery (column 3), and high resistance/fast recovery (column 4). An important note is that the group with a higher number of observations is the most resilient one. In fact, approximately 47% of the Portuguese municipalities have higher resistance and recovery capacities than the average.

Clearly, a preliminary positive relationship between R&I networks and resistance/recovery emerged from Table 1. These R&I–industry collaborations seem to be especially important during the COVID-19 period (as the value is higher in column 3 than in column 2), but it is also important to regions to recover faster in the post-crisis period. Additionally, by observing Table 1, R&I engagement in innovation networks seems to be the most relevant innovation-related variable included in this investigation, since neither R&D researchers, R&I quality, or human capital present higher values for the most resilient groups.

The values of variables related with the 2017–2019 average performance of municipalities (e.g., unemployment, GVA per capita and GFCF per company) suggest that the most hit municipalities were those that performed better in the pre-crisis period, which is in accordance with the COVID-19 literature indicating the disruptive nature of this crisis (e.g., Lopes & Sargento, 2023).

Labor stability presents higher values in regions with a good resistance to the crisis. Finally, municipalities where the percentage of the employment in accommodation sector is significant seem to be less resistance (the percentage is higher in both groups with low resistance, columns 1 and 2) but, within groups with the same level of resistance

**TABLE 1** Summary statistics.

Variable	Low resistance/ slow recovery (1)	Low resistance/ fast recovery (2)	High resistance/ slow recovery (3)	High resistance/ fast recovery (4)
R&I networks (in 1,000 companies)	0.34	0.50	0.68	0.81
R&D researchers (in 1,000 inhabitants)	2.20	1.19	0.98	1.71
R&I quality	2.28	1.73	2.12	2.12
Human capital (%)	14.33	13.35	14.35	13.83
Labor stability (%)	59.48	58.36	68.89	66.80
Pre-crisis unemployment (%)	4.40	4.84	5.69	6.23
Population density (/km ²)	690.94	226.20	87.23	239.89
International trade openness (%)	31.91	21.77	21.95	20.00
Employment in accommodation sector (%)	10.18	12.60	7.02	7.19
Herfindahl–Hirschman Index	1,869.96	1,967.47	1,984.65	1,957.89
COVID-19 intensity (in 10,000 inhabitants)	52.89	35.59	39.71	38.78
GFCF per company	287.03	190.67	154.16	187.26
GVA per capita (1,000 euro)	8.49	6.51	4.94	5.45
Transparence index	53.17	49.27	49.33	52.60
Observations	60	30	57	131

(above or below the average), a higher percentage of accommodation employment is observed in the fast recovery groups (column 2 compared with 1 and column 4 with 3).

4.3 | Model estimations

Column (1) of Table 2 presents the results obtained by estimating regional resistance (Equation 3), and column (2) corresponds to the results of the estimation of Equation (4)—regional recovery. According to the adjusted R^2 , the variables included in the model explain better regional heterogeneity in the resistance phase than in the recovery phase. The mean of variance inflation factor (VIF) tests points to the inexistence of problems related with multicollinearity between explanatory variables.

The positive and statistically significant estimation of α indicates that regions where a higher number of R&I entities collaborate with businesses in innovation-based projects are more resistant to the crisis. These networks are very important for sharing human and physical capital, skills, knowledge, and trust, and to promote spillovers (Di Caro, 2017) that improve ‘the ability of a local system to respond to an external shock’ (Cainelli et al., 2019, p.658). Additionally, a positive effect of R&I networks in regional recovery is also observed, which according to Boschma (2015), may be relevant in further phases of resilience, namely increasing regions' capacity to change and develop new growth paths.

In accordance with the literature (e.g., Crescenzi et al., 2016; Di Caro, 2017; Geelhoedt et al., 2021; Giannakis & Bruggeman, 2017; Lopes & Sargento, 2023), enhanced human capital level seems to reduce territories' vulnerability to unemployment, even in a downturn situation. Indeed, municipalities with higher percentages of workers with a higher education diploma and with more institutions with high quality in R&I are apparently more resistant to crises. Nevertheless, both variables did not reveal statistical significance in the recovery phase (which was also founded in

**TABLE 2** Models (regression output).

Variable	Resistance (1)	Recovery (2)
Constant	-0.2237*	0.0132
R&I networks	0.0267**	0.0314***
R&D researchers	0.0017	0.0006
R&I quality	0.0190***	0.0009
Human capital	0.0048*	-0.0016
Labor stability	0.0027***	0.0003
Pre-crisis unemployment	0.0290***	0.0200***
Population density	-0.0001	0.0001
International trade openness	-0.0017***	-0.0010**
Employment in accommodation sector	-0.0063***	0.0001
Herfindahl-Hirschman Index	-0.0001**	-0.0001
COVID-19 intensity	-0.0001	-0.0002
GFCF per company	0.0001	-0.0001
GVA per capita	-0.0016	0.0028
Transparence index	0.0004	-0.0003
Number of observations	278	278
Adjusted R^2	50.22%	15.41%
F-statistic	14.31 (0.0000)	3.40 (0.0000)
VIF-test (mean)		2.26

Note: Columns (1) and (2) include controls for other sectoral distribution of employment (with primary sector being the baseline sector).

* p -Value <0.1, ** p -Value <0.05, and *** p -Value <0.01.

Geelhoedt et al., 2021, for the case of human capital). R&D researchers have a statistically insignificant coefficient in both columns.

In complete agreement with the literature (for example, Adams-Prassl et al., 2020; Bachmann et al., 2015; Baussola et al., 2015; Fana et al., 2020), a significant and positive effect of the percentage of permanent work contracts on regional resistance was found. As expected, labor stability is very important for protecting individuals/territories from an economic shock, but apparently it is not helpful in the recovery phase where a certain labor flexibility might be important to increase employment.

No significant effect of population density in both the resistance and recovery phases was identified. On the other hand, pre-crisis unemployment significantly affects resistance and recovery, which means that regions with previous lower levels of unemployment were the most hit by this economic shock and the ones that have more struggle in recovery (Cappelli et al., 2021; Giannakis & Bruggeman, 2020; Lopes & Carreira, 2022). This result suggests that, in what concerns the labor market, the COVID-19 downturn does not seem to have contributed to increasing regional inequalities. The gross value added per capita and the GFCF per company are statistically insignificant for both resistance and recovery models.

The strong restrictions imposed on the international mobility of people and products hit tourism very hard and caused disruptions in global value chains (see, e.g., Ferreira et al., 2021), thus justifying that municipalities with significant foreign dependence (through a higher percentage of employment in the accommodation sector or a higher international openness level) were generally less resistance to the COVID-19 crisis. This relation between international dependence and the immediate impact of the COVID-19 crisis is observed in column (1) of Table 2 and was

**TABLE 3** Multinomial logistic regression.

	R&I networks
Low resistance/fast recovery	1.0732*
High resistance/slow recovery	1.0886**
High resistance/fast recovery	1.2732**

*p-Value <0.1, **p-Value <0.05.

also obtained in previous literature—for example, Hu et al. (2022) and Gong et al. (2020), for the economic openness degree, and Lopes et al. (2021) and Fana et al. (2020), in the case of the accommodation sector. In this research, we further found that exports and imports dependence also harm the recovery ability of Portuguese territories.

Higher sector specialization (measured by the Herfindahl–Hirschman Index) is associated with a lower resistance to the crisis, supporting the portfolio diversification argument, as in Geelhoed et al. (2021) and Di Caro (2017).

The coefficients of the COVID-19 intensity were statistically insignificant in both models, which might be related to the fact that, more important than the disease per se, were the policies and measures imposed for containing it, which, in Portugal, were generically applied all over the country.

The coefficient of the transparency index is statistically insignificant in both columns. Other possible proxies for capturing the quality of local government institutions and their degree of response to the crisis were also considered: (a) the European Union funding captured by each municipality in total revenue and (b) local government transfers' variation between 2019 and 2020 (aiming to indirectly capture the significance of local policy measures taken to support households and business in the pandemic). Again, nonsignificant coefficients were obtained. Thus, it seems that local government institutions were not very influential in improving local resilience to the COVID-19 crisis in Portugal. In fact, we note that the majority of policies used to prevent unemployment during the COVID-19 crisis (e.g., the simplified layoff) were applied to all the country by the central government.

In Table 3, we present the coefficients for the main explanatory variable—R&I networks—that are obtained through the estimation of the multinomial logistic model, Equation (7). Notably, the coefficients are positive and statistically significant for the three groups of municipalities compared with the base group. It is, therefore, possible to conclude that the higher the involvement of regional R&I entities in collaborative projects with the business sector, the higher the probability of a municipality not belonging to the less-resilient group. Moreover, the coefficient is higher for the probability of being in the most resilient group (high resistance/fast recovery), which means that R&I networks are essential to a 'better response not only during periods of shock (resistance), but also immediately after the shock (recovery)' (Muštra et al., 2020, p.966).

In the case of the remaining variables, the results are generally consistent with the ones presented in Table 2.⁴ For example, pre-crisis unemployment has a positive coefficient for all the three groups, while human capital and labor market stability are above all important in terms of shock resistance capacity. The exception is the quality of local R&I entities, which is important to explain the resistance capacity when this variable is included as a continuous variable but is not significant to distinguish between municipalities above or below the country-average resistance.

Finally, we also checked for the possibility of the effect of R&I networks on resistance and recovery to vary according to the municipality resilience performance (Filippetti et al., 2020; Kitsos et al., 2023), by estimating Equations (3) and (4) through a quantile regression. We found significant and positive effects on resistance and recovery in all the quantiles except in the lower quantile (q0.1), where the coefficient is positive but nonsignificant in both equations (Table 4). Thus, this last regression suggests for the robustness of our results and the important role that R&I networks have in regional resilience, although not being significantly relevant for the 10% worst-performing municipalities.

⁴These results are not presented in Table 3, but might be made available upon request.

**TABLE 4** Quantile regressions.

	R&I networks	
	Resistance (1)	Recovery (2)
0.1 quantile	0.0052	0.0188
0.25 quantile	0.0234*	0.0450***
0.5 quantile	0.0303**	0.0423***
0.75 quantile	0.0234**	0.0364***

* p -Value <0.1, ** p -Value <0.05, and *** p -Value <0.01.

5 | CONCLUDING REMARKS

A regional resilience framework has been used in this paper to examine Portuguese territorial heterogeneity in resisting and recovering from the COVID-19 crisis and to explore the relevance of territorial determinants in explaining such uneven performance. An emphasis was put on innovation-related variables—particularly R&I networks, which have been overlooked in regional resilience COVID-19-related studies.

The results obtained in this research highlight the relevant role of R&I entities (such as higher education institutions, technological and research centers), particularly through their engagement in innovation co-creation projects together with business partners at the NUT III level. This result shows that, maybe even more important than innovation per se, territories endowed with R&I entities that demonstrate openness to collaborate in innovation networks with firms, exhibit better performance in both resilience phases analyzed: the resistance and the recovery one. This is significant in terms of policy implications, especially in a period when the R&I supporting instruments for the upcoming years are being designed and operationalized within the context of operational programs financed by European Structural and Investment Funds. Besides supporting investment in research and innovation to be made by each individual regional ecosystem actor (enterprises, government entities, and R&I entities), policy-makers might consider putting in place mechanisms to stimulate stronger collaboration between those actors, favoring the transference of knowledge, competencies, and technology.

Additionally, regional structural characteristics have different roles in the phases of resistance and recovery. For example, sectoral diversity and a more qualified labor force are important factors to smooth the immediate impact of the crisis but do not seem to be essential for the Portuguese municipalities to be able to recover. Moreover, labor stability reduces the employment to unemployment movement in crises but, in the recovery stage, some labor flexibility is necessary to facilitate the opposite movement. With regard to foreign dependence, our results suggest that it was easier to recover from the tourism crash caused by COVID-19 than from the impact of this crisis in the international supply chains, thus producing a stronger and longstanding negative effect on regions that are very dependent on the export and import of goods. Policy-makers should also be aware that some determinants that generally contribute to better-performing regional labor markets might not be efficient when facing disruptive and unprecedented crises.

Our work clearly has some limitations. The first is the that, although examining the impact of a global crisis, it has been applied to a specific national context, imposing constraints to the results' generalization. This is particularly acute regarding the effect of innovation networks, for which there is lack of evidence regarding other countries. Second, the high level of geographical detail used (the municipality) does not come without downsides, particularly due to commuting patterns Ferreira et al., 2017; indeed, for a share of each municipality's population, variables determining unemployment resilience may not be related to the same municipality, but to others. Besides, it is expected that unemployment resilience exhibits spatial dependence between municipalities, which is not grasped through the different model formulations adopted in this paper. Thus, future lines of research include, on the one hand, the empirical analysis of a new database built upon the notion of local labor markets (as in Gutiérrez Posada et al., 2018)



instead of municipalities, for which we will need detailed municipality to municipality commuting data, not currently available; on the other hand, the testing of spatial econometric formulations, such as the spatial autoregressive model (as in Angulo et al., 2018). Third, our empirical application is restricted in its timeframe, exploring the short- and medium-term impact of different resilience determinants, leaving aside any considerations about long-run effects. We admit that this weakness is difficult to overcome in the following periods of time, given the high uncertainty that currently characterizes the global panorama, which makes it hard to define a realistic time for the end of the crisis. In fact, right when the global economy was showing signs of recovery after the COVID-19 crisis, another unexpected crisis emerged, provoked by the war in Ukraine and the related economic consequences.

In such context, we believe this research could encourage further studies on regional resilience, across countries, analyzing how regions will react to the ongoing economic crisis. Furthermore, future works should deepen the analysis about the role of innovation-related determinants—human and financial resources, competencies, entrepreneurship dynamics, and innovation networks—not only in the resistance and recovery phases of regional resilience, but also regarding their potential to promote structural changes and renew long-term regional growth paths.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the Institute of Employment and Professional Training for the authorization to use the databases, which were essential for the investigation. We are also grateful to the anonymous referees and to Professor Rui Santos for their helpful comments and suggestions. This paper is financed by National Funds of the Fundação para a Ciência e a Tecnologia—Portuguese Foundation for Science and Technology within the project ‘UIDB/04928/2020.’

ORCID

Ana Sargento  <https://orcid.org/0000-0001-5716-1890>

REFERENCES

- Adams-Prassl, A., Boneva, T., Golin, M., & Rauh, C. (2020). Inequality in the impact of the coronavirus shock: Evidence from real time surveys. *Journal of Public Economics*, 189, 104245. <https://doi.org/10.1016/j.jpubeco.2020.104245>
- Angulo, A., Mur, J., & Trivez, F. (2018). Measuring resilience to economic shocks: An application to Spain. *Annals of Regional Science*, 60(2), 349–373. <https://doi.org/10.1007/s00168-017-0815-8>
- Bachmann, R., Bechara, P., Kramer, A., & Rzepka, R. (2015). Labor market dynamics and worker heterogeneity during the Great Recession—Evidence from Europe. *IZA Journal of European Labor Studies*, 4(19), 19. <https://doi.org/10.1186/s40174-015-0043-0>
- Baussola, M., Mussida, C., Jenkins, J., & Penfold, M. (2015). Determinants of the gender unemployment gap in Italy and the United Kingdom: A comparative investigation. *International Labor Review*, 154, 537–562. <https://doi.org/10.1111/j.1564-913X.2015.00028.x>
- Boschma, R. (2015). Towards an evolutionary perspective on regional resilience. *Papers in Evolutionary Economic Geography*, 49(5), 733–751. <https://doi.org/10.1080/00343404.2014.959481>
- Bristow, G., & Healy, A. (2018). Innovation and regional economic resilience: An exploratory analysis. *Annals of Regional Science*, 60(2), 265–284. <https://doi.org/10.1007/s00168-017-0841-6>
- Cainelli, G., Ganau, R., & Modica, M. (2019). Does related variety affect regional resilience? New evidence from Italy. *Annals of Regional Science*, 62(3), 657–680. <https://doi.org/10.1007/s00168-019-00911-4>
- Capello, R., & Lenzi, C. (2017). Structural dynamics of regional innovation patterns in Europe: The role of inventors’ mobility. *Regional Studies*, 53(1), 30–42. <https://doi.org/10.1080/00343404.2017.1379600>
- Cappelli, R., Montobbio, F., & Morrison, A. (2020). Unemployment resistance across EU regions: The role of technological and human capital. *Journal of Evolutionary Economics*, 31(1), 147–178. <https://doi.org/10.1007/s00191-020-00693-5>
- Cappelli, R., Montobbio, F., & Morrison, A. (2021). Unemployment resistance across EU regions: The role of technological and human capital. *Journal of Evolutionary Economics*, 31(1), 147–178. <https://doi.org/10.1007/s00191-020-00693-5>
- Chen, A., & Groenewold, N. (2022). Regional resilience in China: The response of the provinces to the growth slowdown. *The Review of Regional Studies*, 52, 74–103. <https://doi.org/10.52324/001c.35253>



- Crescenzi, R., Luca, D., & Milio, S. (2016). The geography of the economic crisis in Europe: National macroeconomic conditions, regional structural factors and short-term economic performance. *Cambridge Journal of Regions, Economy and Society*, 9(1), 13–32. <https://doi.org/10.1093/cjres/rsv031>
- Di Caro, P. (2017). Testing and explaining economic resilience with an application to Italian regions. *Papers in Regional Science*, 96(1), 93–113. <https://doi.org/10.1111/pirs.12168>
- Di Caro, P., & Fratesi, U. (2022). The role of cohesion policy for sustaining the resilience of European regional labor markets during different crises. *Regional Studies*, 1–17. <https://doi.org/10.1080/00343404.2022.2118252>
- Faggian, A., Gemmiti, R., Jaquet, T., & Santini, I. (2018). Regional economic resilience: The experience of the Italian local labor systems. *The Annals of Regional Science*, 60(2), 393–410. <https://doi.org/10.1007/s00168-017-0822-9>
- Fana, M., Pérez, S., & Fernández-Macías, E. (2020). Employment impact of Covid-19 crisis: From short term effects to long terms prospects. *Journal of Industrial and Business Economics*, 47, 391–410. <https://doi.org/10.1007/s40812-020-00168-5>
- Ferreira, J., Ramos, P., Barata, E., Court, C., & Cruz, L. (2021). The impact of COVID-19 on global value chains: Disruption in nonessential goods production. *Regional Science Policy & Practice*, 13(S1), 32–54. Portico. <https://doi.org/10.1111/rsp3.12416>
- Ferreira, J.-P., Ramos, P., Cruz, L., & Barata, E. (2017). Modeling commuting patterns in a multi-regional input–output framework: Impacts of an ‘urban re-centralization’ scenario. *Journal of Geographical Systems*, 19(4), 301–317. <https://doi.org/10.1007/s10109-017-0250-5>
- Filippetti, A., Gkotsis, P., Vezzani, A., & Zinilli, A. (2020). Are innovative regions more resilient? Evidence from Europe in 2008–2016. *Economia Politica*, 37, 807–832. <https://doi.org/10.1007/s40888-020-00195-4>
- Geelhoed, F., Royuela, V., & Castells-Quintana, D. (2021). Inequality and employment resilience: An analysis of Spanish municipalities during the Great Recession. *International Regional Science Review*, 44(1), 113–141. <https://doi.org/10.1177/0160017620957056>
- Giannakis, E., & Bruggeman, A. (2017). Determinants of regional resilience to economic crisis: A European perspective. *European Planning Studies*, 25(8), 1394–1415. <https://doi.org/10.1080/09654313.2017.1319464>
- Giannakis, E., & Bruggeman, A. (2020). Regional disparities in economic resilience in the European Union across the urban–rural divide. *Regional Studies*, 54(9), 1200–1213. <https://doi.org/10.1080/00343404.2019.1698720>
- Gong, H., Hassink, R., Tan, J., & Huang, D. (2020). Regional resilience in times of a pandemic crisis: The case of COVID-19 in China. *Tijdschrift voor Economische en Sociale Geografie*, 111(3), 497–512. <https://doi.org/10.1111/tesg.12447>
- Gutiérrez Posada, D., Rubiera Morollón, F., & Viñuela, A. (2018). The determinants of local employment growth in Spain. *Applied Spatial Analysis*, 11, 511–533. <https://doi.org/10.1007/s12061-017-9226-6>
- Hu, X., Li, L., & Dong, K. (2022). What matters for regional economic resilience amid COVID-19? Evidence from cities in Northeast China. *Cities*, 120(May 2021), 103440. <https://doi.org/10.1016/j.cities.2021.103440>
- Kartseva, M. A., & Kuznetsova, P. O. (2020). The economic consequences of the coronavirus pandemic: Which groups will suffer more in terms of loss of employment and income? *Population and Economics*, 4(2), 26–33. <https://doi.org/10.3897/popecon.4.e53194>
- Kitsos, A., & Bishop, P. (2018). Economic resilience in Great Britain: The crisis impact and its determining factors for local authority districts. *Annals of Regional Science*, 60(2), 329–347. <https://doi.org/10.1007/s00168-016-0797-y>
- Kitsos, T., Grabner, S., & Carrascal-Incera, A. (2023). Industrial embeddedness and regional economic resistance in Europe. *Economic Geography*, 99, 227–252. <https://doi.org/10.1080/00130095.2023.2174514>
- Lopes, A., & Carreira, P. (2022). COVID-19 impact on job losses in Portugal: Who are the hardest-hit? *International Journal of Manpower*, 43(5), 1265–1282. <https://doi.org/10.1108/IJM-06-2021-0384>
- Lopes, A., & Sargento, A. (2023). Regional heterogeneity in the individual unemployment vulnerability after COVID-19 outbreak. *International Regional Science Review*. Advance online publication. <https://doi.org/10.1177/01600176231160486>
- Lopes, A., Sargento, A., & Carreira, P. (2021). Vulnerability to COVID-19 unemployment in the Portuguese tourism and hospitality industry. *International Journal of Contemporary Hospitality Management*, 33(5), 1850–1869. <https://doi.org/10.1108/IJCHM-11-2020-1345>
- Martin, R., & Sunley, P. (2015). On the notion of regional economic resilience: Conceptualization and explanation. *Journal of Economic Geography*, 15(1), 1–42. <https://doi.org/10.1093/jeg/lbu015>
- Martin, R., Sunley, P., Gardiner, B., & Tyler, P. (2016). How regions react to recessions: Resilience and the role of economic structure. *Regional Studies*, 50(4), 561–585. <https://doi.org/10.1080/00343404.2015.1136410>
- Morgan, K. (2007). The learning region: Institutions, innovation and regional renewal. In R. Rutten & F. Boekema (Eds.), *The learning region*. Edward Elgar Publishing.
- Muštra, V., Šimundić, B., & Kuliš, Z. (2020). Does innovation matter for regional labour resilience? The case of EU regions. *Regional Science Policy & Practice*, 12(5), 955–970. Portico. <https://doi.org/10.1111/rsp3.12348>
- Palaskas, T., Psycharis, Y., Rovolis, A., & Stoforos, C. (2015). The asymmetrical impact of the economic crisis on unemployment and welfare in Greek urban economies. *Journal of Economic Geography*, 15(5), 973–1007. <https://doi.org/10.1093/jeg/lbv027>



- Partridge, M., Chung, S., & Wertz, S. (2022). Lessons from the 2020 COVID recession for understanding regional resilience. *Journal of Regional Science*, 62(4), 1006–1031. <https://doi.org/10.1111/jors.12584>
- Raagmaa, G., & Keerbergh, A. (2016). Regional higher education institutions in regional leadership and development. *Regional Studies*, 51(2), 260–272. <https://doi.org/10.1080/00343404.2016.1215600>
- Rocchetta, S., Mina, A., Lee, C., & Kogler, D. (2022). Technological knowledge spaces and the resilience of European regions. *Journal of Economic Geography*, 22(1), 27–51. <https://doi.org/10.1093/jeg/lbab001>
- Rutten, R., & Boekema, F. (2007). Regional social capital: Embeddedness, innovation networks and regional economic development. *Technological Forecasting and Social Change*, 74(9), 1834–1846. <https://doi.org/10.1016/j.techfore.2007.05.012>
- Sutton, J., & Arku, G. (2022). Regional economic resilience: Towards a system approach. *Regional Studies, Regional Science*, 9(1), 497–512. <https://doi.org/10.1080/21681376.2022.2092418>
- Wooldridge, J. (2010). *Econometric analysis of cross section and panel data* (Second ed.). The MIT Press.

How to cite this article: Sargento, A., & Lopes, A. S. (2023). Territorial resilience on the aftermaths of COVID-19 crisis—An exploratory analysis on the role of innovation. *Regional Science Policy & Practice*, 1–15. <https://doi.org/10.1111/rsp3.12697>