



# The underlying factors of the COVID-19 spatially uneven spread. Initial evidence from regions in nine EU countries

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## Abstract

The novel coronavirus COVID-19 was brought to the global spotlight in early 2020 and has already had significant impacts on daily life, while the effects could last for a long period. However, these impacts appear to have been regionally differentiated, since similar to previous pandemics, geography plays an important role in viruses' diffusion. This paper enriches our knowledge about the initial territorial impact of the pandemic, from January to May 2020, studying the spread of COVID-19 across 119 regional economies in nine EU countries and explaining its underlying factors. Air quality, demographics, global interconnectedness, urbanization trends, historic trends in health expenditure as well as the policies implemented to mitigate the pandemic were found to have influenced the regionally uneven mortality rate of COVID-19.

## KEYWORDS

COVID-19, EU, regional inequalities, regression

## JEL CLASSIFICATION

R1; R15; H51; I1; I14

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## 1 | INTRODUCTION

Since December 2019, the novel coronavirus COVID-19 has entered our lives and, starting from China, has spread across 215 countries, by the end of May 2020. Although the fatality rate cannot be estimated yet, there are two elements that make COVID-19 a serious threat to human life. First, the high amount of asymptomatic COVID-19 carriers and, second, the high reproduction rate ( $R_0$ ), which shows the number of people being infected by a single patient, being above 2.5 in the early stages of the current outbreak (Benvenuto et al., 2020). Coronavirus and the subsequent policies adopted to address its impacts shook up all aspects of life. However, these effects appear to have been geographically differentiated. Space has played an important role in the development of previous pandemics, with geographical proximity being key to viruses' spread (McLafferty, 2010).

Regions across the European Union have recorded different levels of COVID-19 transmission, adding a layer to the complex mosaic of factors that determine the spatial inequalities in terms of growth (Woods, 2020a). Most patients and deaths caused by COVID-19 have been concentrated in specific regions of Europe, such as Lombardia, Madrid and Paris. Examining the COVID-19 impact at the regional level could provide useful insights, with regions recording different levels of exposure to the virus, even within the same country.

This analytical paper contributes to the study of the initial territorial impact of COVID-19, seeking to examine its spread across regional economies in Western Europe and explain its underlying factors. It focuses on 119 regions in nine EU countries, being among those which so far have been most adversely affected across the globe. The paper examines distinct regional economic, social, demographic and environmental factors and highlights the various policy responses, such as lockdown and social distancing measures (Torre, 2020). Considering the novelty of the situation with COVID-19, the paper tests the role of specific regional features in the spread of the virus already examined in the literature, such as environmental pollution (Zhu, Xie, Huang, & Cao, 2020) and demographics (Dowd et al., 2020), but also sheds light on factors that have not been studied yet, including agglomeration and global interconnectedness. Chiefly, it examines the wider impact of all these factors based on their interaction, employing econometric analysis (Section 4), following the formation of the conceptual framework (Section 2) and the explanation of the methodology and variables employed (Section 3). The last section concludes.

## 2 | GEOGRAPHICAL PATTERNS OF PANDEMICS: DIFFERENT REGIONAL CHARACTERISTICS

Human societies have historically suffered from serious pandemics, whose emergence and growth have increased in the last decades, due to various socio-economic restructurings and behavioural changes. Major examples include changing production and consumption patterns, climate change, demographic transition, growth in international mobility and trade (McLafferty, 2010), as well as the implementation of rolling-back welfare and privatization policies, and the subsequent weakening of health systems (Forster, Kentikelenis, & Bamba, 2018; Humer, Rauhut, & Marques da Costa, 2013). SARS and Ebola are important cases of recent infectious diseases.

Geography has been highlighted as a major explanatory factor of the nature and spread of previous pandemics. Geographers have used the concept of spatial diffusion concept to analyze the geographies of pandemics (Cliff & Haggett, 2006; Sabel, Pringle, & Schaerstrom, 2010). By expanding locally, leading to high regional concentration, or transferring over longer distances, resulting in international spread, viruses diffuse across space, following certain routes, either at the regional level, through commuting, or at the national and international level, via trade and air travel routes (Lai et al. 2009).

The deepening of globalization and the increase in urbanization in the last decades have been important for the pandemics. Globalization has been accompanied by significant advances in communications and medical treatments, that are capable of mitigating the pandemic spread (McLafferty, 2010). Notwithstanding that, globalization comes



together with a considerable rise in mobility and global interconnectedness, as well as the deepening of climate emergency, favouring the emergence and growth of pandemics (King, 2009). Indeed, the increasing trends in global air transport have been key drivers of the spread of previous viruses, such as SARS (Bowen & Laroe, 2006). The growth of urbanized areas and the development of “satellite” towns in peri-urban zones, accelerated by the vast rural-to-urban migration, is an important driver for the spread of a contagious disease, mainly due to the increase of population density and commuting (Connolly, Keil, & Ali, 2020). It should be born in mind that the origins of both SARS and Ebola are to be found in urbanized areas (Keil & Alim, 2007). Against these pandemics, governments have applied mitigation policies, whose nature is largely geographical, seeking to intervene in local environments and interactions among people within them (McLafferty, 2010).

These spatial factors are underpinned by specific regional features to enhance the explanatory framework of the geographical evolution of COVID-19, accounting for the unequal spatial growth of pandemics (Huang & Smith, 2010). As aforementioned, geography and spatial proximity are deemed to be crucial in the COVID-19 spread, due to its high  $R_0$  (Torre, 2020), with high levels of contagion being observed in cases where great concentration of people occurs, such as metropolises.

### 3 | DATA AND METHODOLOGY

To draw a detailed picture of the initial spread of the pandemic outbreak across EU regions, this paper estimates the hitherto number of deaths caused by COVID-19 per 100,000 inhabitants in each region as of 1 May 2020 (mortality rate), based on data sourced from the national statistical agency in each country. This is the dependent variable and was preferred to “people tested positive to COVID-19 *per capita*” (transmission rate), since data on deaths ease comparisons among countries whilst testing policies vary significantly. Some countries decided to conduct aggressive testing, trace the patients and their contacts, and isolate them, while others tested just the serious cases (Ren, 2020). The paper interrogates the way that various regional features interact with the mortality associated with COVID-19. While some of these elements possibly affect only the transmission rate, the selected index is argued to be effective capturing such effects, considering that high COVID-19 transmission is linked to high death rates (Woods, 2020a).

The author employs an ordinary least squares (OLS) cross-sectional multiple regression model that is a frequent and suitable method to estimate the slope and intercept parameters of a dependent variable with cross-sectional data (Wooldridge, 2012). In this case, the OLS model is used to estimate the association between COVID-19 mortality and various regional features, while also capturing the interrelationships among all the explanatory variables. Thus, the methodological strategy adopted captures the wider picture of COVID-19 impact across EU regions. The figures related to the independent variables refer to the year with the latest available data. Data sources include Eurostat, unless otherwise stated. The model takes the following form:

$$Y_r = a_0 + \sum_{\lambda=1}^n (\alpha_\lambda X_{\lambda,r}) + \epsilon_r,$$

where  $Y_r$  is the dependent variable, i.e. COVID-19 deaths per 100,000 inhabitants in each region.  $X_{\lambda,r}$  is the set of  $\lambda$  independent-explanatory variables for region  $r$  under consideration.  $a_\lambda$  is the set of the coefficients of the  $\lambda$  independent variables.  $a_0$  is the value of the dependent variable when the independent variable is zero.  $\epsilon_r$  is the error term that accounts for unobserved factors.

Tests are undertaken for nine countries (Germany, France, Greece, Portugal, Italy, Austria, the Netherlands, Sweden, and Spain). These countries provide a cross section of regions with different levels of deaths caused by COVID-19, as well as different types of government measures to mitigate the pandemic. Based on the territorial level that data for deaths from COVID-19 are available, all the variables are estimated at NUTS 2 level, except for Germany and France, that are calculated at NUTS 1 (figures are available at this level). This research



strategy, combining different NUTS regions, has been employed by other works, when comprehensive data were not available (Martin & Tyler, 2006).

Regarding the data limitations, first, there has not been a consensus around the most appropriate way of measuring COVID-19 related deaths to be shared among different countries. Some countries publish deaths only from victims in the hospitals, while others also include deaths outside hospitals (Comas-Herrera et al., 2020). Second, there are different criteria for death registrations, with some countries including deaths from COVID-19 after a test has been made, and others publishing figures about deaths of persons suspected to have been infected by the virus. Third, there is a timing issue, with some countries recording severe delays to publish deaths caused by COVID-19 that occurred weeks before the publication day. Overall, examining the impact of a pandemic in its early stages entails insufficient data availability.

The following explanatory variables were chosen to examine the regional features that determined the extent of COVID-19 spread. The three key factors include demographics, global interconnectedness and mitigation measures. Table 1 demonstrates the descriptive statistics of all the variables used in this paper.

### 3.1 | Demographics

The demographic profile of regions could be insightful about the spatial distribution of COVID-19, given that the fatality rate (deaths per COVID-19 patients) is much higher in elderly people, particularly in the age groups above 65 years old (Dowd et al., 2020). This paper employs the share of people above 65 years old in the total population of each region (YEAR65). It is hypothesized that regions of aging population demonstrate higher mortality.

**TABLE 1** Descriptive statistics

Variables	Mean	Maximum	Minimum	Standard Deviation	Range	Coefficient of Variation
DEATH	21.60	135.97	0.00	28.62	135.97	1.33
EXP	8784.32	29707.78	181.52	6686.74	29526.26	0.76
GDP	30998.32	64800.00	11800.00	11714.44	53000.00	0.38
BUSZ	4.62	13.25	0.24	2.43	13.00	0.53
HOUSEH	2.87	3.39	2.51	0.14	0.88	0.05
COLLECT	3.20	7.76	0.52	1.77	7.24	0.55
AIRPASS	234832.75	1727771.37	360.92	350054.08	1727410.45	1.49
MOTORD	33.93	205.00	0.00	33.84	205.00	1.00
BEDS	11850.33	97593.50	900.64	14325.89	96692.87	1.21
MANUF	7.92	14.92	1.98	2.51	12.94	0.32
YEAR65	21.19	28.45	10.71	3.26	17.74	0.15
HOSB	465.52	1285.31	158.36	222.04	1126.95	0.48
DOC	413.39	791.92	124.96	112.29	666.96	0.27
AIR	21.63	97.00	5.90	14.24	91.10	0.66
DEATHL	23.36	54.00	3.00	15.87	51.00	0.68
FIRMD	6214.65	12830.40	2701.55	1915.37	10128.84	0.31
CASES	1,296	39,791	624	11,922	39,167	0.92
METROP	0.65	1.00	0.00	0.48	1.00	0.74



## 3.2 | Global interconnectedness

The COVID-19 pandemic has significantly spread through mass travel and transport (Hall, Scott, & Gössling, 2020). This is the reason that EU governments decided to close the intra-EU borders, seeking to mitigate the spread of the coronavirus (Renda & Castro, 2020). On these grounds, regions that are globally interconnected, with high levels of “openness,” through a hundred thousand movements of goods and people on a daily basis, are likely to have recorded a more severe impact. To test global interconnectedness, from the perspective of international trade, the value of exports *per capita* in 2019 (EXP) is estimated, based on data from national statistical agencies. Moreover, motorway density (MOTOR), expressed in kilometres of motorways per thousand square kilometres in 2018, is employed as an index of land freight transport in the region. These variables are expected to be positively correlated to COVID-19 mortality. Another transmission channel is tourism, which has demonstrated strong growth since the 1980s, based on increased global mobility through time and space compression (Niewiadomski, 2020). Two variables are used to examine the impact of tourism. The number of available beds in collective tourist accommodation per 100,000 inhabitants in 2018 (BEDS), and the arrivals of air transport passengers per 100,000 inhabitants in 2018 (AIRPASS). Both predictors are hypothesized to lead to an increase in mortality.

## 3.3 | Mitigation measures

The various policies seeking to mitigate the COVID-19 pandemic may have affected its spread, presenting significant differentiation across space and time (Ren, 2020). While some EU countries decided to follow the “herd immunity” strategy (Sweden and the Netherlands to a certain extent), governments in other countries (such as Spain, Italy and Greece) imposed strict horizontal lockdown and quarantine measures across all their regions (Renda & Castro, 2020). Although they lacked co-ordination (Jordana & Triviño-Salazar, 2020), these lockdown measures prevented or delayed millions of COVID-19 infections (Hsiang et al., 2020). Mitigation policies could include mass gatherings restrictions, home isolation and general lockdown. To test the effects of mitigation policies, two variables are employed, both at the national level, since most EU countries implemented uniform nation-wide lockdown measures. The number of days between the first death caused by COVID-19 and the beginning of lockdown (DEATHL) as well as the number of COVID-19 patients when the lockdown restrictions were applied (CASES). Given that Sweden and the Netherlands have not applied lockdown measures, DEATHL for the regions in these countries is estimated from day of the first death to 1 May 2020, while CASES refer to the same day. It is hypothesized that both variables are positively correlated to COVID-19 mortality.

## 3.4 | Air quality

Air quality is likely to affect the impact of COVID-19 (Zhu et al., 2020). This paper employs the variable AIR that describes the average weekly concentration ( $\mu\text{g}/\text{m}^3$ ) of PM<sub>10</sub>, a particulate matter that has a negative impact on air quality, in the week starting 10 February 2020, according to the measurement stations of the European Environment Agency (2020). In the event that more than one station is present in each region, the average is calculated. It is expected that regions with a high concentration of PM<sub>10</sub> demonstrate higher mortality from COVID-19.

## 3.5 | Industrial structure

Air pollution links to the presence and the level of manufacturing activity in a region. Besides, manufacturing was subject to moderate lockdown restrictions, involving several “essential” economics branches, such as food processing



and manufacture of pharmaceutical products. Regions with higher manufacturing share in total economic activity are more likely to have been adversely affected by COVID-19, since more workers continued going to work, keeping the infection rate high, either through commuting to work via public transport or from physical interactions at the workplace. The paper estimates the share of manufacturing firms in regional business stock in 2017 (MANUF), which is expected to be positively correlated to mortality.

### 3.6 | Size of household/business

Considering the high risk of COVID-19 contagion in cases of individuals' concentration (Walker et al., 2020), the "size" of sites where people spend a significant part of their day could be crucial. Two sites are significant in this field: the household and the workplace. The author estimates the average number of people living in a house (HOUSEH), based on census data of 2011, and the average size of businesses in terms of employment (BUSZ) in 2017.

### 3.7 | Agglomeration/urbanization

Extending the argument of high concentration of people at a larger scale, the role of agglomerations is examined. Urban areas are expected to demonstrate higher death rates, due to the higher concentration of individuals and greater intraregional transportation than rural regions (Connolly et al., 2020). The index of population density ignores the fact that administrative units are largely heterogeneous and unevenly sized across countries, with some municipalities covering larger surfaces than other urban administrative units (OECD, 2012). Therefore, following suggestions made by Zenou (2000), this paper employs the density of firms as an agglomeration index, calculated as the number of businesses per 100,000 inhabitants in 2017 (FIRMD). Moreover, to test the impact of the metropolises on the mortality, the author uses a dummy variable (METROP), related to the presence of a metropolitan or large metropolitan functional urban area in the region (1 = Yes, 0 = No). This paper uses the data and the terminology of OECD which defines metropolis as a densely populated city and a suburban area with a labour market that is largely integrated with the city, which has a total population above 500,000 people (OECD, 2012). In this instance, regions containing a metropolis, according to OECD, are considered as urban.

### 3.8 | Economic dynamism

To further investigate the impact of agglomeration dynamics and considering the lack of available data related to urban/rural typology at the NUTS 2 level, GDP *per capita* is perceived as an additional index of urbanization of a region (de Beer, van der Gaag, & van der Erf, 2014). Regions considered as urban by Eurostat had 21% higher GDP *per capita* than the EU average in 2014, with rural regions recording 28% lower GDP per head (DG Agriculture and Rural Development, 2018). GDP *per capita* (GDP), for 2018, being an index of economic dynamism, combines issues of agglomeration, high global interconnectedness, large firms, and strong tendency for long commutes (Woods, 2020a). Therefore, regions with higher GDP *per capita* are expected to demonstrate greater mortality. However, areas of lower GDP per head are likely to be linked to greater deprivation of the population, with this implying worse health conditions, restricted access to health services, and more people being unable to cease economic activity due to low income, while also limiting the possibility of working remotely, due to the nature of their jobs or access to 'home office' (Torre, 2020).



### 3.9 | Social life

Besides the environmental, demographic and economic factors, institutional aspects, either formal or informal, need to be considered, as they significantly influence the regional socio-economic context (Rodríguez-Pose, 2020). Regarding norms, the lifestyle of elderly people could have affected the regionally uneven impact of the pandemic. There are societies, especially in Northern Europe, within which a culture of formal care for the elderly (care homes) is dominant (Eurofound, 2017). By contrast, in several countries in Southern Europe, care homes are less common, with elderly people either living independently or with their families. Due to the high concentration of elderly people, sharing common facilities, care homes have facilitated COVID-19 transmission (Comas-Herrera et al., 2020). Based on 2011 census data, the author uses the index of share of people above 65 years old living in 'collective living quarters' (COLLECT), i.e. premises where large groups of individuals live all together.

### 3.10 | Health system

Alongside the norms, formal institutions are crucial, with welfare provision and policies related to the health system possibly affecting the impact of COVID-19. This could be more important considering the cuts in health expenditures by EU countries to resolve the 2007/08 global economic crisis, that implied more centralized health systems (Woods, 2020b). The allocation of health expenditure is geographically uneven across the EU, leading to persistent socio-spatial inequalities in terms of access to health services (Forster et al., 2018). Better resourced health systems may have responded more efficiently to the pandemic, minimizing the risk of mortality. To evaluate the impact of the health system conditions in each region, the variables of hospital beds (HOSB) and medical doctors (DOC) per 100,000 inhabitants are employed (2017 data). They are expected to be negatively correlated to COVID-19 mortality.

The model has five different versions to capture the aggregate impact of the explanatory variables on COVID-19 mortality (Appendix A). Each of the five simulations includes different predictors. The author builds on the main assumption that demographics, global interconnectedness and mitigation measures are the key factors that explain the regionally uneven impact of COVID-19. Therefore, to test these three key factors, the variables related to them (YEAR65, EXP, MOTORD, DEATHL, CASES) are included in every version of the model. Different control variables are progressively added in each version of the model to test their impact, but also to indicate that the results related to the key factors do not change. Alternative estimation strategies were employed to test the effects of a broad set of key independent variables and to assess the robustness and stability of the key regressor across various

**TABLE 2** Top ten and bottom ten regions in terms of COVID-19 mortality, as of 1 May 2020

Bottom ten		Top ten	
Region	Mortality	Region	Mortality
Ipeiros (GR)	0	Piemonte (IT)	68.93
Thessalia (GR)	0	Castilla y León (ES)	72.10
Sterea Ellada (GR)	0	Liguria (IT)	74.29
Notio Aigaio (GR)	0	Trento (IT)	76.88
Região Autónoma da Madeira (PT)	0	Emilia-Romagna (IT)	78.75
Alentejo (PT)	0.14	La Rioja (ES)	105.24
Kriti (GR)	0.16	Valle d'Aosta (IT)	109.02
Peloponnisos (GR)	0.17	Castilla-la Mancha (ES)	119.71
Voreio Aigaio (GR)	0.45	Comunidad de Madrid (ES)	122.03
Dytiki Ellada (GR)	0.76	Lombardia (IT)	135.97



estimation methods. Therefore, different variables are used for specific factors (such as HOSB and DOC to test the impact of health funding). In this way, the bias of the results is minimized and their validity increases. For the cross-section regression, the degree of correlation between the explanatory variables should be tested in order to avoid biased estimates. The pairwise correlation matrix did not indicate high correlation between the explanatory variables included in the same version of the model. Finally, the parameter estimates of the control variables in all regression models have been tested for potential multicollinearity. The standard tests based on the variance inflation factor (VIF) reject any degree of multicollinearity, with VIF having values below 10 in all the five simulations (Wooldridge, 2012).

To further increase the robustness of the results, the author checked for the presence of outliers that could bias the results, the normality in the distribution of the variables and heterogeneity of the observations in each variable based on z-score (Wooldridge, 2012). While many variables followed the normal distribution, several were identified to include outliers. To correct heterogeneity and address the issue of outliers driving the significance and direction of the results, the author ran the model without the observations that were identified as outliers (presented in Table 3). The results did not have significant changes with the estimations including the outliers (Appendix B). Moreover, the log was taken to normalize the variable and the model was re-run with no significant changes (Appendix C). Overall, the outliers have been either omitted from the model or the model was run without these observations, with

**TABLE 3** Results of OLS regressions. Dependent variable: deaths per 100,000 inhabitants, as of 1 May 2020.

Model	(1)	(2)	(3)	(4)	(5)
YEAR65	0.173 (0.881)	3.964 <sup>*</sup> (0.073)	2.351 <sup>**</sup> (0.032)	0.859 (0.357)	4.080 <sup>***</sup> (0.009)
EXP	0.001 <sup>**</sup> (0.026)	0.001 (0.516)	0.000 (0.822)	0.001 <sup>*</sup> (0.081)	0.001 (0.204)
DEATHL	0.472 <sup>**</sup> (0.036)				0.278 (0.178)
MOTORD		0.474 <sup>***</sup> (0.005)	0.460 <sup>***</sup> (0.002)		0.249 <sup>*</sup> (0.058)
CASES		-0.001 (0.103)	-0.001 <sup>***</sup> (0.002)	0.000 (0.124)	
AIR	0.946 <sup>***</sup> (0.008)	0.795 <sup>**</sup> (0.032)			
FIRMD	0.002 (0.351)			0.006 <sup>**</sup> (0.033)	
HOUSEH		61.959 (0.169)			70.438 <sup>**</sup> (0.049)
AIRPASS		0.000 (0.650)			0.000 (0.277)
DOC		-0.082 <sup>*</sup> (0.086)		-0.045 (0.169)	
GDP		0.001 <sup>*</sup> (0.063)			
BUSZ			3.732 <sup>**</sup> (0.047)	3.227 (0.154)	
MANUF			1.003 (0.535)		
COLLECT			8.226 <sup>***</sup> (0.001)		
HOSB			-0.122 <sup>***</sup> (0.000)	-0.038 <sup>**</sup> (0.041)	
BEDS				0.000 (0.316)	
METROP					15.560 <sup>*</sup> (0.050)
Constant	-33.440 (0.270)	-266.961 (0.124)	-23.634 (0.284)	-9.933 (0.757)	-301.922 (0.021)
Adjusted R <sup>2</sup>	0.196	0.218	0.303	0.121	0.174
F-Stat	4.905	2.887	6.223	2.835	3.353
VIF	1.3	2.4	2.7	1.9	1.7

Note:

<sup>\*\*\*</sup> statistically significant in 1%,

<sup>\*\*</sup> statistically significant in 5%,

<sup>\*</sup> statistically significant in 10%.



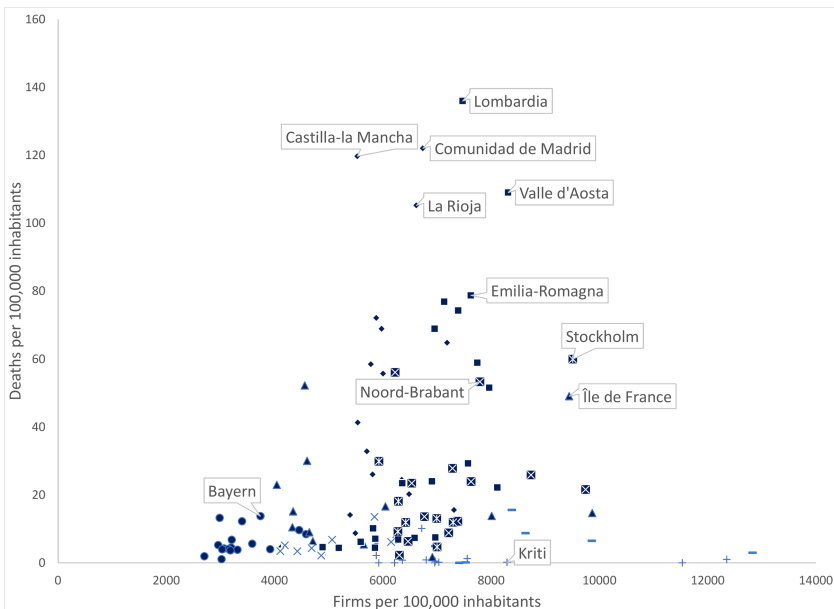


no significant changes of the results. These controls confirm that the validity of the model is not threatened from issues stemming from either a highly skewed distribution of the variables or the presence of outliers.

Regarding the flow of the data, the first part of the analytical section presents the descriptive statistics of the dependent and independent variables (Table 1), including the outliers, before illustrating the COVID-19 mortality rate across the 119 regions (Figure 1). Table 2 presents the findings about the top 10 and bottom 10 regions in terms of COVID-19 mortality, while Figure 2 illustrates evidence on the mean and coefficient of variation (CV) of COVID-19 mortality across the regions in each country. Table 3 shows the results of the OLS regression.

## 4 | EMPIRICAL ANALYSIS OF THE INITIAL IMPACT OF COVID-19 ON EU REGIONS

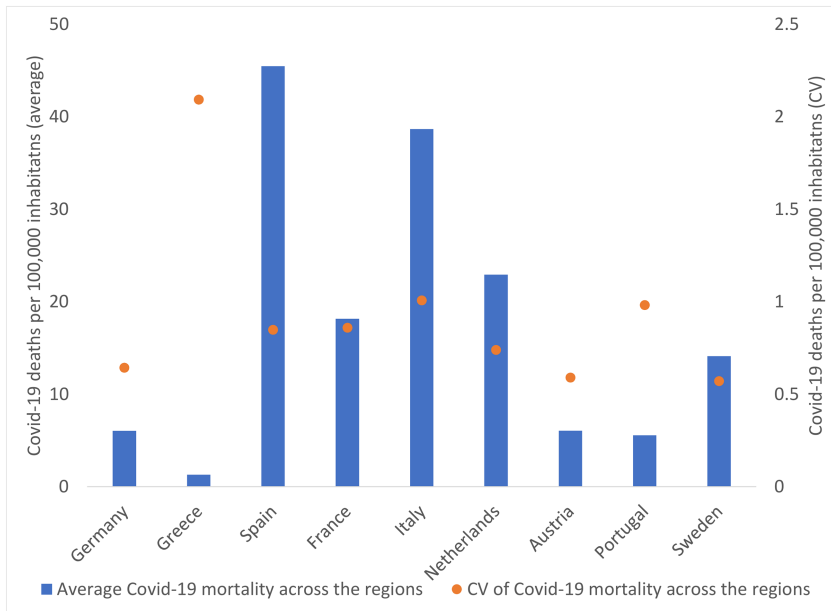
The pandemic evolution has been regionally uneven. Table 1 shows that the CV of mortality was quite high (1.33) across the 119 regions. Figure 1 illustrates the mortality rate, and its positive correlation to agglomeration (firms per 100,000 inhabitants), providing initial insights for the significant impact of the pandemic on regions with large urban centercentres. Lombardia was the EU NUTS 2 region with the highest mortality (136 deaths per 100,000 inhabitants), followed by Comunidad de Madrid (122). Unsurprisingly, these regions are in Italy and Spain, two of the countries experiencing the most severe impact of the pandemic. Italy recorded more than 28,000 deaths from COVID-19 and Spain almost 25,000 victims as of 1 May 2020. These regions are largely urbanized, containing two of the most important metropolises in the EU (Milan and Madrid). By contrast, five regions have not recorded any deaths, with four of them being in Greece (Ipeiros, Thessalia, Sterea Ellada, Notio Aigaiο) and one in Portugal (Região Autónoma da Madeira), which are among the countries with a limited impact from COVID-19. Greece had 140 deaths from COVID-19 and Portugal almost 1,000 as of 1 May 2020.



**FIGURE 1** Correlation between mortality rate and density of firms across selected EU regions

Source: National statistical agencies and own elaboration.

Notes: Regions of each country have different shape. ■ Italy ◆ Spain ▲ France ✕ Netherlands ✕ Sweden + Greece ● Germany = Portugal ✕ Austria



**FIGURE 2** Average mortality and coefficient of variation of COVID-19 mortality across the regions of each country

Source: Own elaboration

Table 2 illustrates the top 10 and bottom 10 regions in terms of mortality. Eight of the bottom 10 regions are in Greece and two in Portugal, while six of the top 10 regions are in Italy and four in Spain. Significant differences are also observed within countries. For instance, in Spain, Castilla-la Mancha recorded 120 deaths per 100,000 inhabitants and La Rioja 106, while Galicia saw only 20 deaths and Comunidad Valenciana 24. In Italy, the mortality rate in Valle d' Aosta was 109 and in Emilia-Romagna 79, whereas in Calabria only four and Umbria seven. In France, Île de France recorded 49 deaths per 100,000 people, while Bretagne only seven. Finally, in Germany, the mortality in Bayern was 14, whereas in Sachsen-Anhalt was only two.

Figure 2 provides more information about the regionally uneven distribution of COVID-19 deaths within the nine states, illustrating evidence on the mean and CV of COVID-19 mortality across the regions in each country. Spain presented the highest average mortality with 45 deaths per 100,000 residents, followed by Italy (39) and the Netherlands (23). By contrast, Greece and Portugal had the lowest average mortality (1 and 6, accordingly). Notwithstanding the above, Greece demonstrated the highest CV of mortality, with this demonstrating the greatest regional concentration of deaths per 100,000 inhabitants. In fact, 41% of COVID-19 deaths were recorded in the capital region of Attiki. Italy had the second highest CV, as 49% of deaths occurred in Lombardia, the EU region suffering the most severe impact. Following Italy, Portugal exhibited a CV of 0.98, with 57% of the deaths being recorded in Norte region. By contrast, Sweden, Austria and Germany witnessed the most equal distribution of deaths across their regions. It is considered that different socio-economic characteristics identified in each region have driven the uneven trajectory of growth of COVID-19.

Table 3 demonstrates the results of the OLS model. The first value shows the coefficient of the independent variable, while the value in the parenthesis indicates the probability value, which determines the statistical significance of each independent variable at each of the three levels (1%, 5%, or 10%). In the different forms of the model, the explanatory variables that are statistically significant include: air pollution, motorway density, value of exports *per capita*, household, size, business size, business density, presence of a metropolitan area, share of people above 65 years old in the regional population, GDP *per capita*, number of days between the first death and the beginning of



lockdown, number of COVID-19 patients when the lockdown restrictions were applied, number of medical doctors per 100,000 inhabitants, and hospital beds per 100,000 inhabitants.

Confirming the proposition of this paper, Table 3 indicates that the share of people above 65 years old in the regional population exhibits a high and positive coefficient. That is, the age structure of a region is significant for the COVID-19 impact, considering that the mortality rate could diverge between two areas with a similar population size but of different age composition (Dowd et al., 2020). The importance of aging population structures in the EU regions is highlighted by the finding that mortality in territories with a share of elderly people in the total population being higher than the average (18.2%) was 23 deaths, while the regions with that share below the average recorded 18 deaths per 100,000 inhabitants.

Closely related to the age structure, the proportion of people aged over 65 residing in care homes was found to exhibit a statistically significant, positive and high coefficient. Associated with aspects of norms and social life, that have a major impact on the regional socio-economic milieu (Rodríguez-Pose, 2020), regions exhibiting a high proportion of elderly individuals living in care homes are likely to be accompanied by higher mortality from COVID-19. Considering the rapid transmission of the virus in places of high concentration of people along with the high fatality risk in elderly population, care homes constitute significant hotspots of COVID-19 transmission (Comas-Herrera et al., 2020). The top 20 regions in terms of rate of elderly people residing in care homes had an average mortality of 16 people. The 20 regions exhibiting the lowest proportion of elderly population living in care homes recorded an average mortality of four people.

Several variables were employed to investigate the role of global interconnectedness. In terms of trade, the variables of motorway density and value of exports *per capita* were found, as expected, to exhibit a positive coefficient, although the exports' coefficient is small. Regions with an important position in the global production networks, being largely interconnected to other places across the globe, record strong international trade activity, with million commodities moving each day. This is likely to increase the mortality of COVID-19 in a region through the great mobility of people shipping goods. The variables capturing the impact of tourism-driven global interconnectedness were found to be either statistically insignificant (air transport passengers) or close to zero (available beds in tourist accommodation).

The transmission of COVID-19 is believed to increase in highly dense sites, where people spend a large part of their daily life (Walker et al., 2020). The regression analysis confirms this hypothesis, with both the household and business size exhibiting high, positive and statistically significant coefficients. Considering the high reproduction rate ( $R_0$ ), large households and firms could constitute significant hotspots of COVID-19, as a single carrier could quickly cause a burst of new infections, and as a result drive the exponential growth of the virus, especially in the case of asymptomatic carriers.

Regarding environmental factors, air quality was found to be positively correlated to COVID-19 mortality. Confirming the proposition of this paper, regions with high average weekly concentration of PM10 were more likely to record greater mortality rates. Indeed, recent evidence shows that the largest number of deaths caused by COVID-19 were found in areas of high air pollution, which has detrimentally affected the health conditions of the local residents (Zhu et al., 2020). Closely associated with air pollution, the share of manufacturing firms in regional business stock was, as expected, positively correlated to the dependent variable, although it was not statistically significant.

The author formed the hypothesis that urban regions, particularly those containing metropolises, accelerate the mortality of COVID-19, based on its high  $R_0$  (Benvenuto et al., 2020). The econometric analysis confirms this hypothesis assessing that the variables of business density (firms per 100,000 inhabitants) and presence of a metropolitan area in the region exhibit high and positive correlation to the regional mortality. Apart from presenting high density, urban regions tend to be associated with greater intraregional transportation (commuting) and residents' limited access to green spaces, that could facilitate social distancing, compared to rural regions (Connolly et al., 2020). From the analysis, it transpires that six of the ten regions experiencing the highest mortality had a metropolis at their core, in contrast to those with the lowest mortality, whereby a metropolis was not an element to their structure. Results show the regions with a metropolis recorded an average of 23 deaths per 100,000 inhabitants, while the



regions without a metropolis demonstrated 18 on average. The regions with firm density higher than the average (6,214 companies per 100,000 residents) saw a mortality rate of 26 deaths, whereas mortality in regions with lower business density than the average was only 16. This evidence indicates that urban regions are likely to witness a higher mortality than the rural territories.

Considering that urban regions have higher GDP *per capita* than rural (DG Agriculture and Rural Development, 2018), the evidence on urbanization is further supported by the findings related to economic dynamism (GDP per head), that indicated a statistically significant and positive correlation to COVID-19 mortality, although with a small coefficient. This underpins recent evidence suggesting a positive correlation of GDP *per capita* to COVID-19 patients in the EU NUTS 2 regions (Woods (2020a)). The analysis of this paper shows that the regions with GDP per head higher than the average (€30,998) recorded 28 deaths per 100,000 inhabitants, whereas mortality in regions with lower GDP *per capita* than the average was 15. The top 10 regions in terms of COVID-19 mortality had an average GDP of €32,190 per head, while the bottom 10 regions €15,140. Based on these findings, it is concluded that the regions of greater economic dynamism, implying greater global interconnectedness and a higher tendency for long commutes (Woods, 2020a), are likely to record higher mortality.

However, it is observed that some regions with a share of elderly people living in care homes, business size and GDP *per capita* being higher than the average, exhibited mortality that was lower than the average. Examples include the regions of Baden-Württemberg, Bayern, and Berlin in Germany, as well as Wien, Steiermark and Salzburg in Austria. These countries have achieved to keep the mortality rate low (7.5 deaths per 100,000 inhabitants in Germany and 6.3 in Austria as of 1 May 2020), a fact that is closely linked to the policies put forward to mitigate COVID-19, which significantly vary among the EU countries (Ren, 2020), from “herd immunity” responses to strict lockdown measures (Renda & Castro, 2020). With regard to formal institutions, mitigation policies were found to have affected the regionally uneven mortality of COVID-19. The number of days between the first death and the beginning of lockdown was statistically significant and positively correlated to the COVID-19 mortality, confirming the hypothesis of this paper.

The variable associated with the number of COVID-19 patients when the lockdown restrictions were applied was, unexpectedly, found to have a negative, albeit small, impact on the mortality rate. Due to the lack of testing in the beginning of the pandemic, it was mostly the people brought into hospital that were tested for COVID-19. Therefore, the number of cases in the beginning of the pandemic was closely related to the patients in hospital, where they could be possibly treated. By contrast, some people died at home from COVID-19 and were never tested. Dying from COVID-19 in hospital, and thus being recorded as a confirmed case, should be less likely than dying from the virus at home. Therefore, regions with high number of COVID-19 cases, that were likely to be under treatment in hospital, could record lower death rate than regions with lower level of COVID-19 cases.

The measures implemented by the national governments to mitigate the virus impacts present a significant degree of differentiation across countries in terms of timing and restrictiveness. This partly indicates the lack of EU-wide co-ordination regarding the response against the COVID-19, as the EU governments underestimated the virus (Jordana & Triviño-Salazar, 2020). European countries borrowed time, considering the fact that the first case was officially recorded two months after the outbreak of COVID-19 in China. However, most EU states downplayed the risk of the virus. Delays in addressing and negligence in containing the virus' outbreak through “testing, tracing, and isolating” the patients are components of their failure to control the pandemic, contrary to countries which performed better by following this containment strategy (Ren, 2020). In light of these events, the EU countries resorted to extreme mitigation policies, implementing horizontal lockdown measures for all the residents in all the regions, regardless of the virus' evolution, thus raising issues of unfair treatment for residents of regions with low spread of COVID-19 (Woods, 2020b). Regions in countries with the fastest reaction against the pandemic, having implemented lockdown measures at the earliest point after the first death, have been less affected, since lockdown effectiveness increases in case of early implementation. Portugal offered the swiftest response, applying the first lockdown measures 3 days after the first death, followed by Austria (4 days) and Greece (10 days). Except for Sweden and the

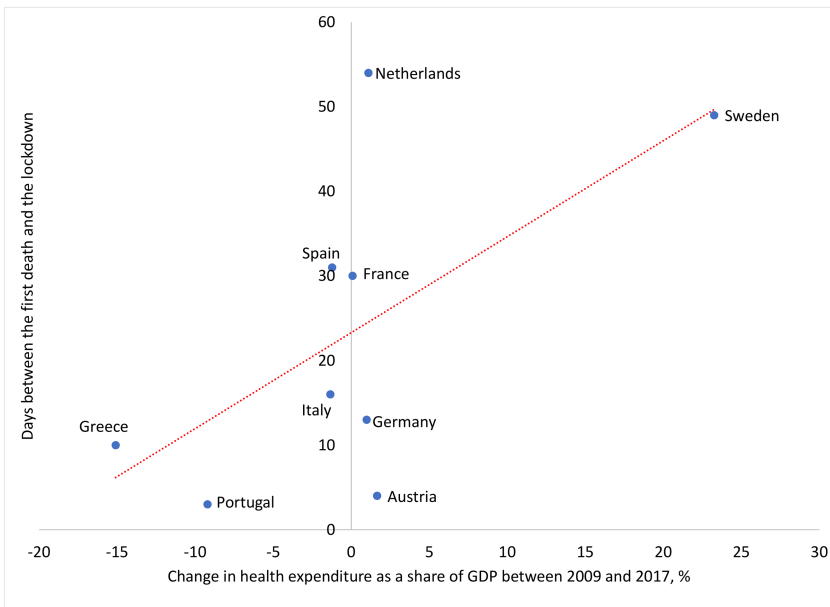


Netherlands, which did not implement a general lockdown, Spain and France had the slowest response (31 and 30 days respectively).

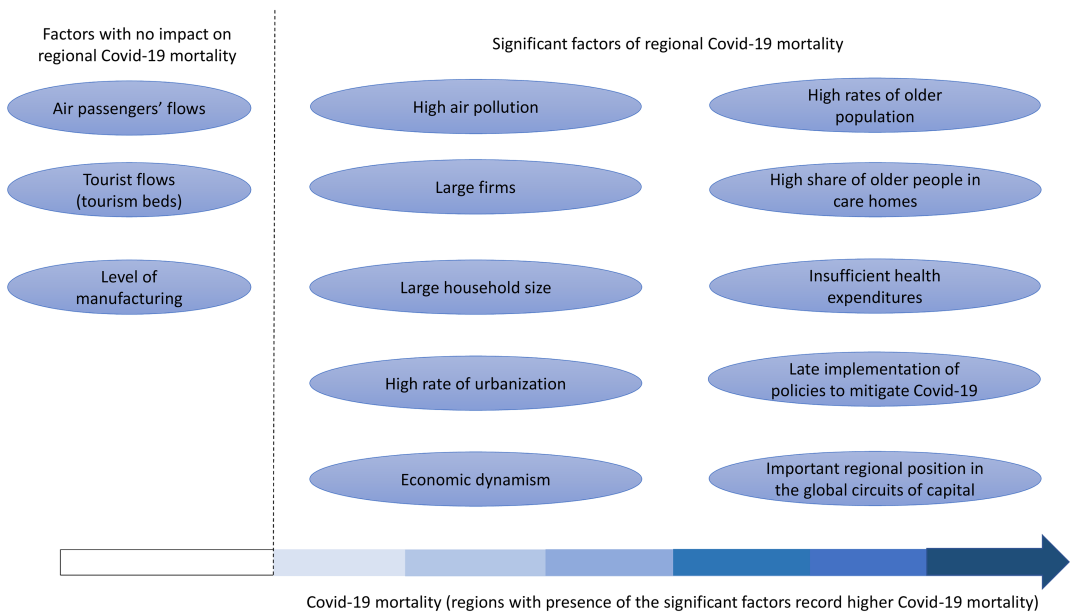
Besides timing, the restrictiveness of mitigation measures appears to vary significantly across the EU (Torre, 2020). Sweden abandoned the idea of pursuing a lockdown strategy, restricting only mass gatherings, while the Netherlands imposed the closure of non-essential services without giving a “stay at home” order. By contrast, Italy and Spain pursued the most restrictive strategy, shutting down educational facilities, non-essential firms, and many manufacturing companies, while not allowing people to exercise outdoors. While these policies appear to have slowed down the diffusion of the pandemic, strategies focusing only on lockdown measures and neglecting the principle of “test, trace and isolate” undermined their effectiveness (Ren, 2020), with thousands of victims, especially in cases of late intervention. The application of lockdown measures even a week earlier could have significantly reduced the COVID-19 cases (Orea & Álvarez, 2020).

From a policy perspective, the persistent and continuous efforts of rolling-back welfare being put forward during the neoliberal era, since the 1980s, appear to have played an important role in the strategies to mitigate the impacts of COVID-19. Many Western governments have chosen not to sufficiently fund the health systems, but to accelerate privatization, amplifying existing socio-spatial inequalities (Forster et al., 2018), that are also expressed at the regional level across the EU (Humer & Palma, 2013). Confirming the hypotheses, regions with a higher number of medical doctors and hospital beds per 100,000 inhabitants are likely to record lower mortality rates, showcasing the significance of regional inequalities in terms of access to health services. Regions having a number of hospital beds below the average (465 beds per 100,000 residents) exhibited much higher mortality than regions with a number above the average (28 victims to 11). Similarly, regions with fewer medical doctors than the average (413 doctors per 100,000 inhabitants) witnessed higher mortality than the areas with more doctors (22 people to 20).

By pursuing “hollowing-out the state” strategies (Rhodes, 1994), state responsibilities have moved sideways since the 1980s, with health services often being provided by private bodies or public-private partnerships. Such policies have weakened the health systems, exposing them to the risk of being overwhelmed in cases of pandemic and increasing socio-spatial inequalities of access to public health, particularly in light of the substantial cuts imposed in



**FIGURE 3** Correlation between health expenditure change and timing of lockdown implementation, with trend line  
Source: Eurostat and own elaboration



**FIGURE 4** The basic regional features that increase the mortality and the factors with no impact

Source: Own elaboration.

Note: The different colors in the arrow indicate the level of COVID-19 mortality in relation to the presence of these significant factors

health expenditures to resolve the 2007/08 crisis (Karanikolos et al., 2013). For instance, in Greece, that witnessed a detrimental impact from the crisis, health expenditure declined from 9.47% of GDP in 2009 to 8.04% in 2017. In Spain, that was also significantly affected by the crisis and has recorded high mortality from COVID-19, health expenditure as a share of GDP fell from 9.08% in 2011 to 8.87% in 2017. In Portugal, another EU country having experienced a serious impact from the 2007/08 crisis, health expenditure declined from 9.88% of GDP in 2009 to 8.97% in 2017. It is quite important to observe in Figure 3 that the countries facing cuts in health expenditure reacted earlier against the pandemic than the countries that increased their health expenditure as a share of GDP. In other words, the early implementation of strict lockdown measures, in countries such as Greece, Portugal and Italy, was an implication of the severe degradation that their health systems have been faced with, as a result of the public cuts to achieve fiscal balance against the crisis.

Figure 4 summarizes the basic elements that proved to increase the mortality of COVID-19 in a region. In other words, it illustrates the significant factors of regional COVID-19 mortality. Regions with strong presence of these economic, demographic, socio-political and environmental conditions are likely to witness a severe impact from the pandemic. It also presents the factors with no important impact on regional COVID-19 mortality.

## 5 | CONCLUSION

The COVID-19 has been accounted for more than 600,000 deaths, having infected more than 14 million people, by the middle of July 2020. Considering that geography has played a significant role in the transmission of previous pandemics (McLafferty, 2010), this paper enriched our knowledge about the impact of space in the spread of COVID-19. It is important to understand that the effects of pandemics are geographically differentiated (Huang & Smith, 2010), in order to examine the nature and development of these viruses. Similar to previous pandemics, COVID-19 has had an uneven spatial diffusion and geographical impact, in terms of deaths. This paper contributed



to the analysis of the initial territorial effects of COVID-19, studying its mortality across regions and explaining its underlying factors.

This paper found that the demographics, average household and business size, air quality as well as care home tradition were significant regional features determining the uneven mortality rate of COVID-19 across 119 regions in nine EU countries. Moreover, global interconnectedness, economic dynamism, and urbanization trends proved to be crucial determinants for the impact of the virus in a region. Finally, historic trends in health expenditure as well as the policies implemented to mitigate the pandemic were also found to have influenced the spatially uneven growth of COVID-19.

A region with high mortality is likely to have large households and firms, as well as a high share of people over 65 years old in the total population. Mortality is greater where a high rate of elderly people living in care homes is identified, while high levels of air pollution are also positively correlated to death rate. High global interconnectedness of a region, in terms of trade, highlights its important position in the global circuits of capital, exposing the area in high volumes of commodities and people shipping them, thereby increasing the COVID-19 mortality. From a policy perspective, regions in countries faced with public cuts that have weakened the health systems, in terms of medical doctors and hospital beds, have witnessed higher mortality. Regions in countries being subject to a swift government response in mitigating the virus have seen a lower mortality rate. Finally, regions with high mortality rates tend to be urban, owing to the presence of a metropolis, exhibiting a high firm density and GDP *per capita*. In the light of the evidence, it is argued that COVID-19 could be considered as a pandemic of the metropolises, with rural areas being affected the least.

The COVID-19 pandemic is a breakthrough in the policy discourse around health systems as well as the working and living patterns. The growth of metropolises, which are accompanied by densely populated building blocks and large companies, raises skepticism over the impacts on workers' mental health linked to longer commutes and insufficient access to public green spaces, which in the context of COVID-19 had more serious health implications. The pandemic and its severe effects could facilitate the reconsideration of policies related to health systems. Governments have focused on rolling-back welfare policies, undermining the effectiveness of the health systems, when assessed against their equipment with medical staff, infrastructure and facilities. The tendency for the privatization of health systems should be also reassessed, since it has left the most vulnerable parts of Western societies without satisfactory social protection and health services. Finally, the governments' decisions to resolve this health crisis have indicated that containment policies, seeking to test, track and isolate the COVID-19 cases, have been the most efficient way to reduce mortality rates (Ren, 2020). By contrast, mitigation policies focusing on horizontal nation-wide lockdowns have been less effective, raising questions about whether a swifter response could have crucially changed the outcome in terms of mortality. In fact, health expenditure policies and the timing of lockdown implementation were strongly correlated, with countries recording the greatest public cuts being the first ones to apply lockdown policies.

On these grounds, and considering the results of this paper, about the uneven impact of COVID-19 in different types of regions and the territories mostly affected, strategies for reacting to a possible forthcoming "second wave" of infections could be locally and regionally tailored, according to the needs of each region, with possible implementation of local containment and mitigation policies. These measures could mitigate the spread of the virus in a specific region, while also preventing outbreaks in approximate areas. Policy tools could include higher protection of elderly residents of the care homes, as well as more frequent testing and possible self-isolation of people moving across regions and countries. The "test, trace and isolate" policy for the regional population could come to the forefront of policy responses, with a greater focus on the residents of large urban areas, and governments acting proactively. All these policy interventions require generous funding and immediate financial support of the health systems to address effectively a potential second wave of infections, until a possible vaccine becomes available.

Considering that we are still in the initial outbreak of COVID-19, and more data are likely to become available in the short term, future research could provide useful insights for the geography of the pandemic. Future work could study the effects of the pandemic on the structural spatial disparities. Bearing in mind the lack of available data related to urban/rural typology at the NUTS 2 level, scholars can expand the understanding of the uneven impact of



COVID-19 by analysing differences according to specific types of regions, such as urbanized vs rural and core vs peripheral regions, but also at different levels of spatial organization, including NUTS 3 regions.

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## APPENDIX A.

### THE FIVE DIFFERENT VERSIONS OF THE MODEL

1.  $Mortality_r = \alpha_0 + \alpha_1YEAR65_r + \alpha_2EXP_r + \alpha_3DEATHL_r + \alpha_4AIR_r + \alpha_4FIRMD_r + \varepsilon_r$
2.  $Mortality_r = \alpha_0 + \alpha_1YEAR65_r + \alpha_2EXP_r + \alpha_3MOTORD_r + \alpha_4CASES_r + \alpha_5AIR_r + \alpha_6HOUSEH_r + \alpha_7AIRPASS_r + \alpha_8DOC_r + \alpha_9GDP_r + \varepsilon_r$
3.  $Mortality_r = \alpha_0 + \alpha_1YEAR65_r + \alpha_2EXP_r + \alpha_3MOTORD_r + \alpha_4CASES_r + \alpha_5BUSZ_r + \alpha_6MANUF_r + \alpha_7COLLECT_r + \alpha_8HOSB_r + \varepsilon_r$
4.  $Mortality_r = \alpha_0 + \alpha_1YEAR65_r + \alpha_2EXP_r + \alpha_3CASES_r + \alpha_4FIRMD_r + \alpha_5DOC_r + \alpha_6BUSZ_r + \alpha_8HOSB_r + \alpha_9BEDS_r + \varepsilon_r$
5.  $Mortality_r = \alpha_0 + \alpha_1YEAR65_r + \alpha_2EXP_r + \alpha_3DEATHL_r + \alpha_4MOTORD_r + \alpha_5HOUSEH_r + \alpha_6AIRPASS_r + \alpha_7METROP_r + \varepsilon_r$



## APPENDIX B.

## RESULTS OF OLS REGRESSIONS WITH THE OUTLIERS

**TABLE A1** Dependent variable: deaths per 100,000 inhabitants, as of 1 May 2020

Model	(1)	(2)	(3)	(4)	(5)
YEAR65	0.273 (0.812)	2.684 (0.194)	1.909 <sup>*</sup> (0.095)	0.810 (0.374)	3.530 <sup>**</sup> (0.012)
EXP	0.001 <sup>*</sup> (0.053)	0.000 (0.934)	0.000 (0.908)	0.001 <sup>**</sup> (0.042)	0.001 (0.335)
DEATHL	0.513 <sup>**</sup> (0.018)				0.406 <sup>**</sup> (0.034)
MOTORD		0.242 <sup>*</sup> (0.064)	0.271 <sup>**</sup> (0.045)		0.138 (0.192)
CASES		0.001 (0.270)	0.001 <sup>*</sup> (0.072)	0.000 (0.242)	
AIR	0.547 <sup>**</sup> (0.022)	0.813 <sup>*</sup> (0.008)			
FIRMD	0.003 (0.111)			0.004 (0.115)	
HOUSEH		44.330 (0.251)			69.892 <sup>**</sup> (0.015)
AIRPASS		0.001 (0.943)			0.000 (0.324)
DOC		0.08 <sup>**</sup> (0.035)		0.044 (0.134)	
GDP		0.001 <sup>**</sup> (0.037)			
BUSZ			1.507 (0.410)	1.085 (0.581)	
MANUF			0.848 (0.606)		
COLLECT			6.483 <sup>**</sup> (0.010)		
HOSB			0.091 <sup>***</sup> (0.000)	0.030 <sup>*</sup> (0.073)	
BEDS				0.000 <sup>*</sup> (0.062)	
METROP					17.393 <sup>**</sup> (0.016)
Constant	31.647 (0.289)	179.686 (0.240)	10.799 (0.631)	8.352 (0.780)	287.066 (0.008)
Adjusted R <sup>2</sup>	0.164	0.199	0.205	0.108	0.164
FStat	4.327	2.929	4.191	2.719	3.442
VIF	1.2	2.6	2.6	2.1	1.7

Note:

<sup>\*\*\*</sup> statistically significant in 1%,

<sup>\*\*</sup> statistically significant in 5%,

<sup>\*</sup> statistically significant in 10%.



## APPENDIX C.

## RESULTS OF OLS REGRESSIONS WITH LOG, CORRECTING FOR HETEROGENEITY

**TABLE A2** Dependent variable: deaths per 100,000 inhabitants, as of 1 May 2020

Model	(1)	(2)	(3)	(4)	(5)
YEAR65 (log)	2.506 (0.912)	57.837 (0.132)	49.326** (0.044)	19.741 (0.295)	89.421*** (0.004)
EXP (log)	10.459*** (0.004)	6.423 (0.306)	5.946 (0.223)	9.849*** (0.002)	6.976* (0.099)
DEATHL	0.368* (0.088)				0.363 (0.104)
MOTORD (log)		10.874** (0.023)	14.942*** (0.001)		7.876* (0.054)
CASES		0.000 (0.394)	0.001*** (0.008)	0.000 (0.134)	
AIR (log)	16.817** (0.012)	19.826** (0.012)			
FIRMD (log)	15.863 (0.161)			34.011** (0.020)	
HOUSEH (log)		147.215 (0.148)			245.763*** (0.004)
AIRPASS (log)		0.010 (0.998)			2.495 (0.250)
DOC (log)		22.978 (0.154)		16.320 (0.166)	
GDP		0.001 (0.277)			
BUSZ			0.814 (0.643)	0.508 (0.798)	
MANUF			0.226 (0.890)		
COLLECT			4.270 (0.132)		
HOSB (log)			38.697*** (0.003)	6.411 (0.393)	
BEDS (log)				8.320** (0.028)	
METROP					9.531 (0.302)
Constant	270.486 (0.038)	333.469 (0.164)	7.777 (0.932)	205.393 (0.184)	643.748 (0.001)
Adjusted R <sup>2</sup>	0.223	0.241	0.281	0.169	0.183
FStat	5.867	3.362	5.352	3.899	3.402
VIF	1.3	2.4	2.5	2.1	1.6

Note:

\*\*\* statistically significant in 1%,

\*\* statistically significant in 5%,

\* statistically significant in 10%.